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Introduction

Water provides a medium to transport nutrients necessary for plant life and make them available for absorption by the roots. Water quality is essential for this process to work at maximum potential. The laws of physics govern plant water uptake. Applying these laws, a grower can provide precise, properly balanced components to grow outstanding marijuana indoors.

Microscopic root hairs absorb water and nutrients in the oxygen present in the growing medium and carry them up the stem to the leaves. This flow of the water from the soil through the plant is called the *transpiration stream*. A fraction of the water is processed and used in photosynthesis. Excess water evaporates into the air, carrying waste products along with it via the stomata in the leaves. This process is called *transpiration*. Some of the water also returns manufactured sugars and starches to the roots.

The roots support the plants, absorb nutrients, and provide the initial pathway into the vascular system. A close-up look at a root reveals the xylem and phloem core, vascular tissue that is enveloped by a cortex tissue or the layer between the internal vascular and the external epidermal tissue. The microscopic root hairs are located on the epidermal tissue cells. These tiny root hair follicles are extremely delicate and must remain moist. Root hairs must be protected from abrasions, drying out, extreme temperature fluctuations, and harsh chemical concentrations. Plant health and well-being is contingent upon strong, healthy roots.



Look at a rooting clone. Check out the fine, fuzzy roots closely. You can see the minute hair-like feeder roots.

The nutrient absorption begins at the root hairs, and the flow continues throughout the plant via the vascular system. Absorption is sustained by diffusion. In the process of diffusion, water and nutrient ions are uniformly distributed throughout the plant. The intercellular spaces—apoplasts and connecting protoplasm, symplast—are the pathways that allow the water and nutrient ions and molecules to pass through the epidermis and the cortex to the xylem and phloem's vascular bundles. The xylem channels the solution through the plant while phloem tissues distribute the food manufactured by the plant. Once the nutrients are transferred to the plant cells, each cell accumulates the nutrients it requires to perform its specific function.

The solution that is transported through the vascular bundles or veins of a plant has many functions. This solution delivers nutrients and carries away the waste products. It provides pressure to help keep the plant structurally sound. The solution also cools the plant by evaporating the water via the leaves' stomata.

Water Quality

Hard Water

The concentration of calcium (Ca) and magnesium (Mg) indicate how "hard" the water is. Water containing 100 to 150 milligrams of calcium (CaCO_3) per liter is acceptable to grow marijuana. "Soft" water contains less than 50 milligrams of calcium per liter and should be supplemented with calcium and magnesium.



Roots on this clone have reached the wall of the container.

Sodium Chloride and Water Quality

Water with high levels of chloride frequently contains high levels of sodium, but the opposite is not true. Water with high levels of sodium does not necessarily contain excessive levels of chloride (chlorine).

At low levels sodium appears to bolster yields, possibly acting as a partial substitute to compensate for potassium deficiencies. But when excessive, sodium is toxic and induces deficiencies of other nutrients, primarily potassium, calcium, and magnesium.

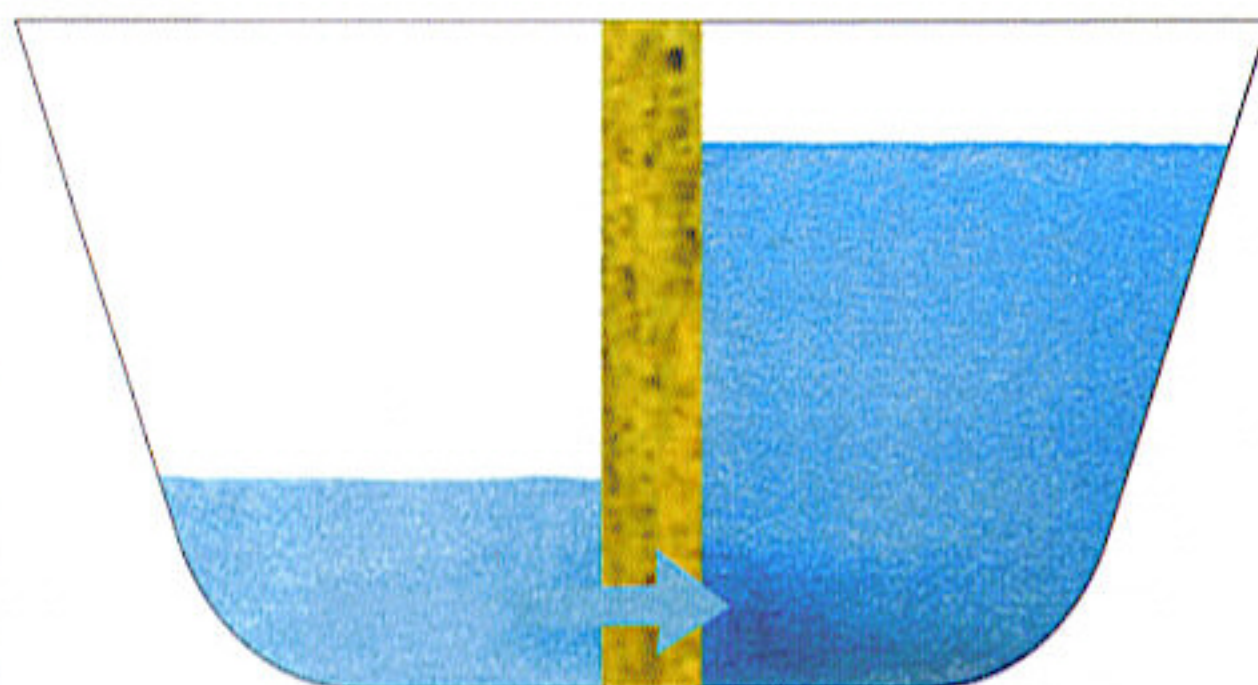
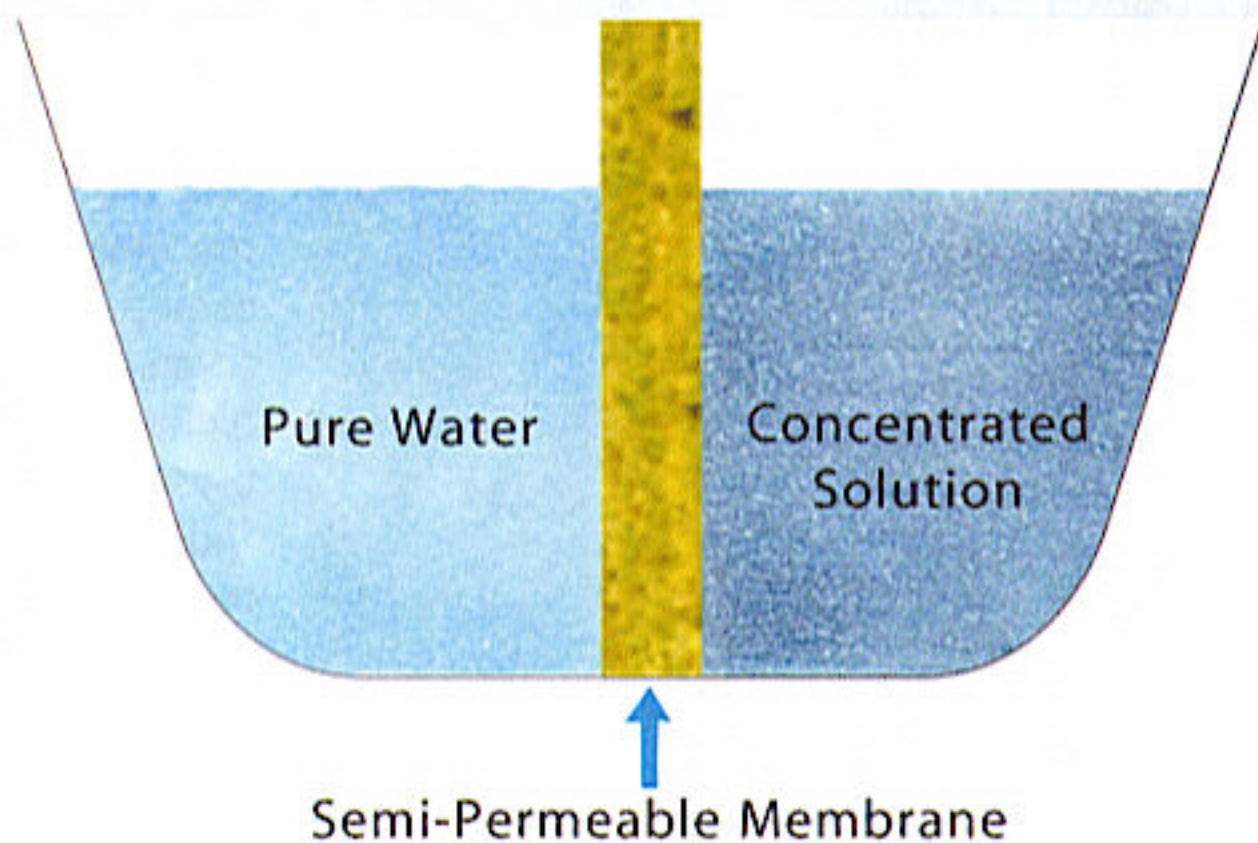
Chloride (chlorine) is essential to the use of oxygen during photosynthesis, and it is necessary for root and leaf cell division. Chloride is vital to increase the cellular osmotic pressure, modify the stomata regulation, and augment

the plant's tissue and moisture content. A solution concentration of less than 140 parts per million (ppm) is usually safe for marijuana, but some varieties may show sensitivity when foliage turns pale green and wilts. Excessive chlorine causes the leaf tips and margins to burn and causes the leaves to turn a bronze color.

Simple water filters do not clean dissolved solids from the water. Such filters remove only debris emulsified (suspended) in water; releasing dissolved solids from their chemical bond is more complex. A reverse-osmosis machine uses small polymer, semi-permeable membranes that allow pure water to pass through and filter out the dissolved solids from the water. Reverse-osmosis machines are the easiest and most efficient means to clean raw water.



Check the pH of the irrigation water and adjust when necessary.



The drawing shows that pure water with no salts or dissolved solids migrates to the solution with more dissolved solids.

Osmosis

The roots draw the nutrient solution up the plant by the process of osmosis. Osmosis is the tendency of the fluids to pass through a semi-permeable membrane and mix with each other until the fluids are equally concentrated on both sides of the membrane. Semi-permeable membranes located in the root hairs allow specific



This reverse osmosis machine transforms water with a high ppm or EC into water with less than 10 ppm.

**STORE IN A COOL DRY PLACE
AWAY FROM DIRECT SUNLIGHT**

TYPICAL ANALYSIS

	mg/l		mg/l
CALCIUM.....	55	SULPHATE.....	13
MAGNESIUM.....	19	NITRATE.....	<0.1
POTASSIUM.....	1	IRON.....	0
SODIUM.....	24	ALUMINIUM.....	0
BICARBONATE.....	248	DRY RESIDUE	
CHLORIDE.....	37	AT 180°C.....	280

pH AT SOURCE.....7.4

The dissolved solids in this bottled water are measured in milligrams per liter (m/l).

nutrients that are dissolved in the water to enter the plant while the other nutrients and impurities are excluded. Since salts and sugars are concentrated in the roots, the electrical conductivity (EC) inside the roots is (almost) always higher than that outside the roots. Transporting the nutrients by osmosis works, because it depends on relative concentrations of each individual nutrient on each side of the membrane; it does not depend on the total dissolved solids (TDS) or EC of the solution. For nutrients to be drawn in by the roots via osmosis, the strength of the individual elements must be greater than that of the roots.

But, the transport of water (instead of nutrients) across the semi-permeable membrane depends on EC. For example, if the EC is greater outside the roots than inside, the plant dehydrates as the water is drawn out of the roots. In other words, salty water with a high EC can dehydrate the plants.

Reverse-osmosis machines are used to separate the dissolved solids from the water. These machines move the solvent (water) through the semi-permeable membrane, but the process is reversed. It moves from lower concentrations to higher. The process is accomplished by applying pressure to the "tainted" water to force only "pure" water through the membrane. The water is not totally "pure" with an EC of "0," but most of the dissolved solids are removed. The efficiency of reverse osmosis depends on the type of membrane, the pressure differential on both sides of the membrane, and the chemical composition of the dissolved solids in the tainted water.

Unfortunately, common tap water often contains high levels of sodium (Na), calcium (Ca), alkaline salts, sulfur (S), and chlorine (Cl). The pH could also be out of the acceptable 6.5 to 7 range. Water containing sulfur is easily smelled and tasted. Saline water is a little more difficult to detect. Water in coastal areas is generally full of salt that washes inland from the ocean. Dry regions that have less than 20-inches-annual rainfall also suffer from alkaline soil and water that is often packed with alkaline salts.

Table salt, sodium chloride (NaCl), is added to many household water systems. A small amount of chlorine, below 140 ppm, does not affect marijuana growth, but higher levels cause foliage chlorosis and stunt growth. Do not use salt-soft-

ened water. Salty, brackish, salt-softened water is detrimental to cannabis. Chlorine also tends to acidify soil after repeated applications. The best way to get chlorine out of the water is to let it sit one or two days in an open container. The chlorine will evaporate (volatilize) as a gas when it comes in contact with the air. If chlorine noticeably alters soil pH, adjust it with a commercial "pH UP" product or hydrated lime.

The metric system facilitates the measurement of "dry residue per liter." Measure the dry residue per liter by pouring a liter of water on a tray and allowing it to evaporate. The residue of dissolved solids that remains after all of the water evaporates is the "dry residue per liter." The residue is measured in grams. Try this at home to find out the extent of impurities. Fertilizers have a difficult time penetrating root tissue when they must compete with resident dissolved solids.

Water that is loaded with high levels of dissolved solids (salts in solution) is possible to manage but requires different tactics. Highly saline water that contains sodium will block the uptake of potassium, calcium, and magnesium. Salt-laden water will always cause problems. If water contains 300 ppm or less dissolved solids, allow at least 25 percent of the irrigation water to drain out of the bottom of containers with each watering. *If raw water contains more than 300 ppm of dissolved solids, use a reverse-osmosis device to purify the water.* Add nutrients to pure water as a way to avoid many nutrient problems.

Dissolved salts, caused by saline water and fertilizer, quickly build up to toxic levels in container gardens. Excessive salts inhibit seed germination, burn the root hairs and tips or edges of leaves, and stunt the plant. Flush excess salt buildup from growing mediums by applying two gallons of water per gallon of medium and repeat leaching using a mild pH-corrected fertilizer solution. Leach growing medium every two to four weeks, if using soft water or saline water. Hard water and well water in dry climates are often alkaline, and usually contain notable amounts of calcium and magnesium. Cannabis uses large quantities of both nutrients, but too much calcium and magnesium can build up in soil. In general, water that tastes good to people also tastes good to cannabis.

Irrigation

Large plants use more water than small plants, but there are many more variables than size that dictate a plant's water consumption. The age of the plant, container size, soil texture, temperature, humidity, and ventilation all contribute to water needs. Change any one of these variables, and the water consumption will change. Good ventilation is essential to promote a free flow of fluids, transpiration, and rapid growth. The healthier a plant, the faster it grows and the more water it needs.



Flushing plants with plain water will wash out most built-up toxic salts. Flush again with a diluted nutrient solution.



Plants in small containers require more frequent watering.



When they are small, plants in medium-sized containers can be watered every other day.



A water meter takes the guesswork out of watering. Remember to keep probes clean for an accurate reading.



Tip the containers to check if they are heavily laden with water. Irrigate the light containers.



Add a few drops of biodegradable liquid dish soap concentrate to the irrigation water. Detergent makes the water penetrate the soil more thoroughly.

Small plants with a small root system in small containers must be watered often. Water frequently—as soon as the soil surface dries out. If exposed to wind, the small plants will dry out very quickly.

Irrigate soil and soilless mixes when they are dry one-half inch below the surface. As long as the drainage is good, it is difficult to overwater fast-growing cannabis. Four-week-old clones flowering in 2- to 3-gallon (7.5 to 11 L) containers need to be irrigated once or twice daily. In fact, most growers prefer smaller containers because they are easier to control.

Irrigate larger plants in the vegetative and flowering stages when soil is dry one-half inch below the surface. Flowering marijuana uses high levels of water to carry on rapid floral formation. Withholding the water stunts the flower formation.

Plants that are exposed to wind dry out much faster. Outdoor, terrace, and patio plants will use up to three or four times more water on a hot, windy day. Keeping up with the watering is difficult and time-consuming. Use an automated watering system or break the wind to lessen its impact on the plants. Mulch will also lessen the evaporation from the soil.

Use plenty of water, and allow up to 10 percent runoff during each watering. The runoff will prevent the fertilizer from building up in the soil. Water early in the day, so excess water will evaporate from the soil surface and the leaves. Leaving the foliage and the soil wet overnight invites a fungal attack.

Moisture meters take most of the guesswork out of irrigating. They can be purchased for less than \$30 and are well worth the money. The meter measures exactly how much water the soil contains at any level or point. Often the soil will not hold the water evenly, and it develops dry pockets. Checking the moisture with a finger provides an educated guess but disturbs the root system. A moisture meter will give an exact moisture reading without disturbing the roots.

Cultivate the soil surface to allow the water to penetrate evenly and guard against dry soil pockets. It also keeps the water from running down the crack between the inside of the pot and the soil and out the drain holes. Gently break up and cultivate the top half inch of the soil with your fingers or a salad fork. Be careful not to disturb the tiny surface roots.

After you develop some skill at knowing when the plants need water, you can check to see how heavy they are simply by tipping them. Once you get the hang of it, all you will have to do is tip each container.

It is easier to keep pots in straight lines when growing and watering, and it is much easier to keep track of watered pots when they are in a straight line.

Overwatering is a common problem, especially with small plants. Too much water drowns the roots by cutting off their supply of oxygen. If you have symptoms of overwatering, buy a moisture meter! It will let both you and your garden breathe

easier. Sometimes, parts of the soil are overwatered and other soil pockets remain bone-dry. Cultivating the soil surface, allowing even water penetration, and using a moisture meter will overcome this problem. One of the main causes of overwatering is poor air ventilation! The plants need to transpire water into the air. If there is nowhere for this wet, humid air to go, gallons of water are locked in the grow room air. Well-ventilated air carries this moist air away, replacing it with fresh, dry air. If using trays to catch runoff water, use a turkey baster, large syringe, or sponge to draw the excess water from the tray. Signs of overwatering are: leaves curled down and yellowed, waterlogged and soggy soil, fungal growth, and slow growth. Symptoms of overwatering are often subtle, and inexperienced gardeners may not see any blatant symptoms for a long time.

Marijuana does not like soggy soil. Soil kept too wet drowns the roots, squeezing out the oxygen. This causes slow growth and possible fungal attack. Poor drainage is most often the cause of soggy soil. It is compounded by poor ventilation and high humidity.

Underwatering is less of a problem; however, it is fairly common if small (1-2 gallon) pots are used and the grower does not realize the water needs of rapid growing plants. Small containers dry out quickly and may require daily watering. If forgotten, water-starved plants become stunted. Once tender root hairs dry out, they die. Most growers panic when they see their prize-marijuana plants wilt in bone-dry soil. Dry soil, even in pockets, makes root hairs dry up and die. It seems to take forever for the roots to grow new root hairs and resume rapid growth.

Add a few drops (one drop per pint) of a biodegradable, concentrated liquid soap like Castille® or Ivory® to the water. It will act as a wetting agent by helping the water penetrate the soil more efficiently, and it will guard against dry soil pockets. Most soluble fertilizers contain a wetting agent. Apply about one-quarter to one-half as much water/fertilizer as the plant is expected to need, and then wait 10 to 15 minutes for it to totally soak in. Apply more water/fertilizer until the soil is evenly moist. If trays are underneath the pots, let excess water remain in the trays a few hours or even overnight before removing it with a large turkey baster.

Another way to thoroughly wet pots is to soak the containers in water. This is easy to do with small pots. Simply fill a 5-gallon (19 L) bucket with 3 gallons (11 L) of water. Submerge the smaller pot inside the larger pot, for a minute or longer, until the growing medium is completely saturated. Wetting plants thoroughly insures against dry soil pockets.

Having a readily accessible water source is very convenient, and it saves time and labor. A 4 × 4-foot garden containing 16 healthy plants in 3-gallon (11 L) pots needs 10 to 25 gallons



Put a saucer under the plants to retain irrigation water, if they run out of water quickly.



Plants in small containers require more frequent watering.



A water wand with a breaker head mixes air with irrigation water just before applying.



A water wand with an air breaker head oxygenates water and splits it into many streams.



Use a filter with drip systems!



Spaghetti tubing is anchored in the growing medium with a spike. A stream of nutrient solution flows out the tubing and percolates down through the growing medium.

(40-100 L) of water per week. Water weighs eight pounds a gallon (1 kg per L). That's a lot of containers to fill, lift, and spill. Carrying water in containers from the bathroom sink to the garden is okay when plants are small, but when they are large, it is a big, sloppy, regular job. Running a hose into the garden saves much labor and mess. A lightweight, half-inch hose is easy to handle and is less likely to damage the plants. If the water source has hot and cold water running out of the same tap, and it is equipped with threads, attach a hose and irrigate with tepid water. Use a dishwasher coupling if the faucet has no threads. The hose should have an on/off valve at the outlet, so water flow can be controlled while watering. A rigid water wand will save many broken branches while leaning over to water in tight quarters. Buy a water wand at the nursery or construct one from plastic PVC pipe. Do not leave water under pressure in the hose for more than a few minutes. Garden hoses are designed to transport water, not hold it under pressure, which may cause it to rupture.

To make a siphon or gravity-fed water system, place a barrel, at least four feet high, in the grow room. Make sure it has a lid to reduce the evaporation and the humidity. If the grow room is too small for the barrel, move it to another room. The attic is a good place because it promotes good pressure. Place a siphon hose in the top of the tank, or install a PVC on/off valve near the bottom of the barrel. It is easy to walk off and let the barrel overflow. An inexpensive device that measures the gallons of water added to the barrel is available at most hardware stores. You can also install a float valve in the barrel to meter out the water and retain a constant supply.

Drip systems deliver nutrient solution one drop at a time or in low volume, via a low-pressure plastic pipe with friction fittings. Water flows down the pipe and out the emitter one drop at a time or at a very slow rate. The emitters that are attached to the main hose are either spaghetti tubes or a nozzle dripper actually emitting from the main hose. Drip irrigation kits are available at garden stores and building centers. You can also construct your own drip system from component parts.

Drip systems offer several advantages. Once set up, drip systems lower watering maintenance. Fertilizer may also be injected into the irrigation system (fertigation); naturally, this facilitates fertilization but gives the same amount of water and nutrient to each plant. If setting up a drip system, make sure the growing medium drains freely to prevent soggy soil or salt buildup. If you are growing clones that are all the same age and size, a drip system would work very well. However, if you are growing many different varieties of plants, they may need different fertilizer regimens.

I interviewed several growers that loved the convenience and constant feeding-ability of their drip systems. All the growers irrigated (fertigated) with mild nutrient solution. They mixed the nutrient solution in a reservoir and pumped it through plastic feeder hoses. They also grew clones in smaller containers and kept root growth to a minimum by keeping the nutrients and the water in constant supply.

A drip system attached to a timer disperses nutrient solution at regular intervals. If using such a system, check the soil for water application daily. Check several pots daily to ensure they are watered evenly and that all the soil gets wet. Drip systems are very convenient and indispensable when you have to be away for a few days. However, do not leave a drip system on its own for more than four consecutive days, or you could return to a surprise!

Drip systems cost a few dollars to set up, but with the consistency they add to a garden, their expense is often paid off by a bountiful yield. Be careful! Such an automated system could promote negligence. Remember that gardens need daily care. If everything is automated, the garden still needs monitoring. All the vital signs: moisture, pH, ventilation, humidity, etc., still need to be checked and adjusted daily. Automation, when applied properly, adds consistency, uniformity, and usually a higher yield.

One indoor grower I met was out of town for five consecutive days every week. He watered and fertilized his plants. He put containerized plants in a tray with 2-inch-tall (6 cm) sides and watered the plants from above until the tray was full of water. He left for five days, and the plants needed no watering while he was gone. He used regular potting soil and added about 10 percent perlite. His plants needed maintenance when he returned, but the plants grew quite well.

Misdiagnosed Disorders

Many indoor garden problems, and to a lesser degree outdoor problems, are misdiagnosed as a lack of fertilizer. Often, disease and insects cause such problems. Other times, problems are caused by an imbalanced pH of the growing medium and water. A pH between 6.5 and 7 in soil and 5.8 to 6.5 in hydroponics will allow nutrients to be chemically available; above or below this range, several nutrients become less available. For example, a full point movement in pH represents a tenfold increase in either alkalinity or acidity. This means that a pH of 5.5 would be ten times more acidic than a pH of 6.5. In soil, a pH below 6.5 may cause a deficiency in calcium, which causes root tips to burn and leaves to get fungal infections and dead spots on foliage. A pH over 7 could slow down the plant's iron intake and result in chlorotic leaves causing veins to yellow.



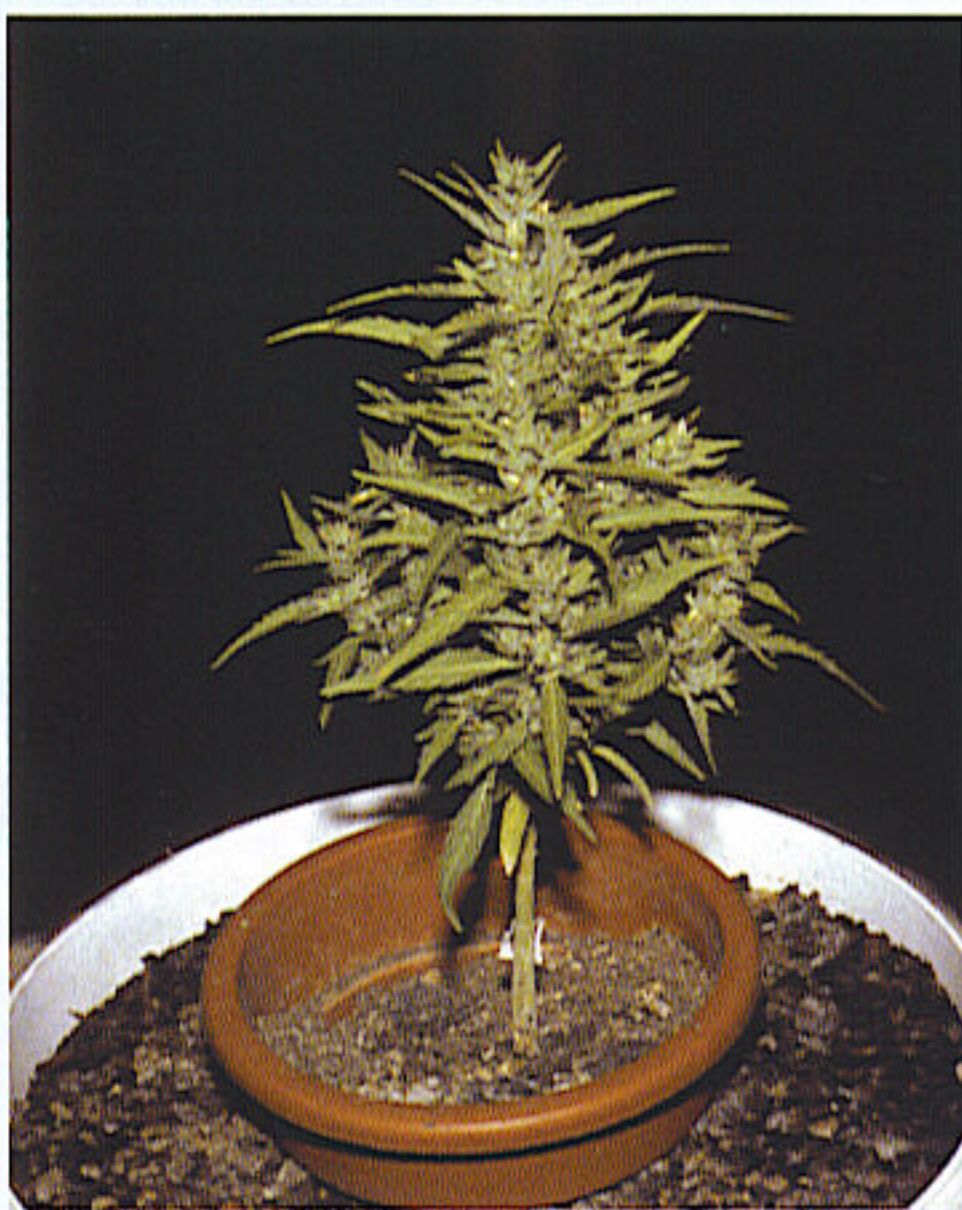
Heat stress makes calyxes stretch up and grow beyond a compact bud.



Light burned this leaf. It appeared only on one leaf under the light.



Light burned this bud. Light burn could be mistaken for overfertilization or fungus. The dead foliage makes a perfect place for bud mold to start!



Water and heat stress caused our little "Lolita" to dwarf. The roots cooked in the hot sun which arrested development.



Leaf fringe standing up – Leaf fringes that point up mean the leaf is trying to dissipate as much moisture as possible, but it is unable to. This could be caused by toxic salt buildup, lack of water, or heat stress.

Incorrect pH contributes to most serious nutrient disorders in organic-soil gardens. Many complex biological processes occur between organic fertilizers and the soil during nutrient uptake. The pH is critical to the livelihood of these activities. When the pH fluctuates in a hydroponic garden, the nutrients are still available in the solution for uptake, and the pH is not as critical. Electrical conductivity is the most critical indicator of plant health and nutrient uptake in hydroponics.

Once a plant shows symptoms, it has already undergone severe nutritional stress. It will take time for the plant to resume vigorous growth. Correct identification of each symptom as soon as it occurs is essential to help plants retain vigor. Indoor, greenhouse, and some outdoor marijuana crops are harvested so fast that plants do not have time to recover from nutrient imbalances. One small imbalance could cost a week of growth. That could be more than 10 percent of the plant's life!



Here is another prime example of heat stress coupled with salt buildup and a lack of Zn, Fe, and Mn.



Big ridges between veins along with curled leaf fringes signify temperature stress coupled with salt build up.

Do not confuse nutrient deficiencies or toxicities with insect and disease damage or poor cultural practices.

The temperature within the leaves can climb to an excess of 110°F (43°C). It happens easily because the leaves store the heat radiated by the lamp. At 110°F (43°C), the internal chemistry of a marijuana leaf is disrupted. The manufactured proteins are broken down and become unavailable to the plant. As the internal temperature of the leaves climbs, they are forced to use and evaporate more water. About 70 percent of the plant's energy is used in this process.

The basic elements of the environment must be checked and maintained at specific levels to avoid problems. Check each of the vital signs—air, light, soil, water, temperature, humidity, etc.—and fine-tune the environment, especially ventilation, before deciding that plants are nutrient deficient.

Nutrient deficiencies are less common when using fresh potting soil fortified with micronutrients. If the soil or water supply is acidic, add dolomite lime to buffer the soil pH and to keep it sweet. Avoid nutrient problems by using fresh planting mix, clean water, and a complete nutrient solution. Maintain the EC and pH at proper levels, and flush the system with mild nutrient solution every four weeks.

COMMON CULTURAL PROBLEMS

Here is a short list of some of the most common cultural problems. Some of them result in nutrient deficiencies.

1. Lack of ventilation: Leaves are stifled and unable to function, causing slow growth and poor consumption of water and nutrients.
2. Lack of light: Nutrients are used poorly, photosynthesis is slow, stems stretch, and growth is scrawny.
3. Humidity: High humidity causes the plants to use less water and more nutrients. Growth is slow because stomata are not able to open and increase the transpiration. Low humidity stresses the plants because they use too much water.
4. Temperature: Both low and high temperatures slow the growth of plants. Large fluctuations in temperature—more than 15 to 20°F or 8 to 10°C—causes slow growth and slows the plant's process.
5. Spray application damage: Sprays are phytotoxic, and they can burn the foliage if the spray is too concentrated or if sprayed during the heat of the day.
6. Ozone damage: See Chapter Thirteen "Air," for more information on ozone damage.
7. Overwatering: Soggy soil causes a menagerie of problems. It cuts the air from the roots, which retards the nutrient intake. The plant's defenses weaken. Roots rot when severe.
8. Underwatering: Dry soil causes nutrient transport to slow severely. It causes nutrient deficiencies and sick foliage, and the roots die.
9. Light burn: Burned foliage is susceptible to pest and disease attack.
10. Indoor air pollution: This causes very difficult-to-solve plant problems. Always be aware of chemicals leaching or vaporizing from the pressboards and other building materials. Such pollution causes plant growth to slow to a crawl.
11. Hot soil: Soil over 90°F (32°C) will harm the roots. Often, outdoor soil that is used in the containers warms up to well over 100°F (38°C).
12. Roots receiving light: Roots turn green if the light shines through the container or the hydroponic system. Roots require a dark environment. Their function slows substantially when they turn green.

Nutrients

Nutrients are elements that the plant needs to live. Carbon, hydrogen, and oxygen are absorbed from the air and the water. The rest of the elements, called *nutrients*, are absorbed from the growing medium and nutrient solu-

Chart of Mobile and Immobile Nutrients

Nitrogen (N)	mobile
Phosphorus (P)	mobile
Potassium (K)	mobile
Magnesium (Mg)	mobile
Zinc (Zn)	mobile
Calcium (Ca)	immobile
Boron (B)	immobile
Chlorine (Cl)	immobile
Cobalt (Co)	immobile
Copper (Cu)	immobile
Iron (Fe)	immobile
Manganese (Mn)	immobile
Molybdenum (Mo)	immobile
Selenium (Se)	immobile
Silicon (Si)	immobile
Sulfur (S)	immobile

tion. Supplemental nutrients supplied in the form of a fertilizer allow marijuana to reach its maximum potential. Nutrients are grouped into three categories: macronutrients or primary nutrients, secondary nutrients, and micronutrients or trace elements. Each nutrient in the above categories can be further classified as either *mobile* or *immobile*.

Mobile nutrients—nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and zinc (Zn)—are able to translocate, move from one portion of the plant to another as needed. For example, nitrogen accumulated in older leaves translocates to younger leaves to solve a deficiency. The result, deficiency symptoms appear on the older, lower leaves first.

Immobile nutrients—calcium (Ca), boron (B), chlorine (Cl), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), silicon (Si) and sulfur (S)—do not translocate to new growing areas as needed. They remain deposited in their original place in older leaves. This is the reason deficiency symptoms appear first in the upper, new leaves on top of the plant.

Mobile nutrients translocate within a plant. They move to the specific part of the plant where they are needed; this causes the older leaves to show deficiencies first.

Macronutrients

Nitrogen (N) - mobile

Practical Information: Marijuana loves nitrogen and requires high levels of it during vegetative growth but lower levels during the balance of life. Nitrogen is easily washed away and must be replaced regularly, especially during vegetative growth. Excess levels of nitrogen in harvested plants cause the dried marijuana to burn poorly.

Technical Information: Nitrogen regulates the cannabis plant's ability to make proteins essential for new protoplasm in the cells. Electrically charged nitrogen allows the plant to tie proteins, hormones, chlorophyll, vitamins, and enzymes together. Nitrogen is essential for the production of amino acids, enzymes, nucleic acids, and chlorophyll and alkaloids. This important nutrient is mainly responsible for leaf and

I would like to thank the scientists at Canna Coco, Breda, Netherlands for information about nutrient deficiencies and toxicities in cannabis. The research team at Canna has been experimenting with cannabis in their fully-equipped scientific laboratory for 20 years. Mauk, head scientist, has made numerous discoveries, and proven them scientifically, about the nutritional needs of the cannabis plant. Hit their web site at

www.canna.com

stem growth, as well as overall size and vigor. Nitrogen is most active in young buds, shoots, and leaves. Ammonium (NH_4^+) is the most readily available form of nitrogen. Be careful when using too much of this form; it can burn the plants. Nitrate (NO_3^-)—the nitrate form of nitrogen—is much slower to assimilate than ammonium. Hydroponic fertilizers use this slower-acting nitrogen compound and mix it with ammonium.

Deficiency: Nitrogen is the most common nutrient deficiency. The symptoms include slow growth. Lower leaves cannot produce chlorophyll and become yellow between the veins while the veins remain green. Yellowing progresses through the entire leaf, eventually causing it to die and drop off. Stems and the leaves' undersides may turn reddish-purple, but this can also be a sign of a phosphorus deficiency. Nitrogen is very mobile, and it dissipates into the environment quickly. It must be added regularly to sustain fast-growing gardens.

Progression of deficiency symptoms at a glance:

Older leaves yellow between the veins (interveinal chlorosis).

Older bottom leaves turn entirely yellow.

More and more leaves yellow. Severely affected leaves drop.

Leaves might develop reddish-purple stems and veins on leaf undersides.

Progressively younger leaves develop interveinal chlorosis.

All foliage yellows and the leaf drop is severe.

Treat deficiency by fertilizing with N or a complete N-P-K fertilizer. You should see results in four to five days. Fast-acting organic sources of nitrogen include seabird guano, fish emulsion, and blood meal. Growers also report excellent results by adding bio-fertilizers (see *Additives* below) to stimulate the uptake of nitrogen.

Toxicity: An overdose of nitrogen will cause excessively lush foliage that is soft and susceptible to stress, including insect and fungal attacks. The stems become weak and they may fold over easily. The vascular transport tissue breaks down, and water uptake is restricted. In severe cases, leaves turn a brownish-copper color, dry,

and fall off. Roots develop slowly, and they tend to darken and rot. Flowers are smaller and sparse. Ammonium toxicity is most common in acidic soils, while nitrate toxicity is more prevalent in alkaline soil.

Progression of toxicity symptoms at a glance:

Excessively lush, green foliage.

Weak stems that fold over.

Slow root development.

Flowers become wispy.

Leaves brown, dry, and fall off.

Treat toxicity by flushing the growing medium of the affected plants with a very mild, complete fertilizer. Severe problems require that more water be flushed through the growing medium to carry away the toxic elements. Flush a minimum of three times the volume of water for the volume of the growing medium. Do not add more fertilizer that contains nitrogen for one week so the excess nitrogen in



Beginning of N deficiency.



Progression of N deficiency.



Later stage of N deficiency.



Early stage of N overdose.



Later stage of N overdose.

foliage can be used. If the plants remain excessively green, cut back on the nitrogen dose.

Phosphorus (P) - mobile

Practical Information: Cannabis uses the highest levels of phosphorus during germination, seedling, cloning, and flowering. Super Bloom fertilizers, designed for flowering, have high levels of phosphorus.

Technical Information: Phosphorus is necessary for photosynthesis and provides a mechanism for the energy to transfer within the plant. Phosphorus—one of the components of DNA, many being enzymes and proteins—is associated with overall vigor, resin, and seed production. The highest concentrations of phosphorus

are found in root-growing tips, growing shoots, and vascular tissue.

Deficiency A lack of phosphorous causes stunted growth and smaller leaves; leaves turn bluish-green and blotches often appear. Stems, leaf stems (petioles), and main veins turn reddish-purple starting on the leaf's underside. NOTE: The reddening of the stems and the veins is not always well pronounced. The leaf tips of older leaves turn dark and curl downward. Severely affected leaves develop large purplish-black necrotic (dead) blotches. These leaves later become bronzyish-purple, dry, shrivel up, contort, and drop off. Flowering is often delayed, buds are uniformly smaller,

seed yield is poor, and plants become very vulnerable to fungal and insect attack. Phosphorus deficiencies are aggravated by clay, acidic, and soggy soils. Zinc is also necessary for proper utilization of phosphorus.

Deficiencies are somewhat common and are often misdiagnosed. Deficiencies are most common when the growing-medium pH is above 7 and phosphorus is unable to be absorbed properly; the soil is acidic (below 5.8) and/or there is an excess of iron and zinc; the soil has become fixated (chemically bound) with phosphates.

Progression of deficiency symptoms at a glance:

Stunted and very slow-growth plants.

Dark bluish-green leaves, often with dark blotches.

Plants are smaller overall.

When blotches overcome the leaf stem, the leaf turns bronzyish-purple, contorts, and drops.

Treat deficiency by lowering the pH to 5.5-6.2 in hydroponic units; 6 to 7 for clay soils; and 5.5-6.5 for potting soils so phosphorus will become available. If the soil is too acidic, and an excess of iron and zinc exists, phosphorous becomes unavailable. If you are growing in soil, mix a complete fertilizer that contains phosphorus into the growing medium before planting. Fertigate with an inorganic, complete hydroponic fertilizer that contains phosphorus. Mix in the organic nutrients—bat guano, steamed bone meal, natural phosphates, or barnyard manure—to add phosphorus to soil. Always use finely ground organic components that are readily available to the plants.

Toxic signs of phosphorus may take several weeks to surface, especially if excesses are buffered by a stable pH. Marijuana uses a lot of phosphorus throughout its life cycle, and many varieties tolerate high levels. Excessive phosphorus interferes with calcium, copper, iron, magnesium, and zinc stability and uptake. Toxic symptoms of phosphorus manifest as a deficiency of zinc, iron, magnesium, calcium and copper; zinc is the most common.

Treat toxicity by flushing the growing medium of affected plants with a very mild and complete



Early stage of P deficiency.



Progression of P deficiency.



Later stage of P deficiency.

fertilizer. Severe problems require more water to be flushed through the growing medium. Flush a minimum of three times the volume of water for the volume of the growing medium.

Potassium (K) - mobile

Practical Information: Potassium is used at all stages of growth. Soils with a high level of potassium increase a plant's resistance to bacteria and mold.

Technical information: Potassium helps combine sugars, starches, and carbohydrates, which is essential to their production and movement. It also is essential to growth by cell division. It increases the chlorophyll in the foliage and helps to regulate the stomata openings so plants make better use of the light and air. Potassium is essential in the accumulation and translocation of carbohydrates. It is necessary to make the proteins that augment the oil content and improve the flavor in cannabis plants. It also encourages strong root growth and is associated with disease resistance and water intake. The potash form of potassium oxide is (K_2O).

Deficiency Potassium-starved plants initially appear healthy. Deficient plants are susceptible to disease. Symptoms include the following: older leaves (first tips and margins, followed by whole leaves) develop spots, turn dark yellow, and die. Stems often become weak and sometimes brittle. Potassium is usually present in the soil, but it is locked in by high salinity. First, leach the toxic salt out of the soil and then apply a complete N-P-K fertilizer. Potassium deficiency causes the internal temperature of the foliage to climb and the protein cells to burn or degrade. Evaporation is normally highest on leaf edges, and that's where the burning takes place.

The progression of the deficiency symptoms at a glance:

Plants appear healthy with dark green foliage. The leaves lose their luster.

Branching may increase, but the branches are weak and scrawny.

Leaf margins turn grey and progress to a rusty-brown color, and then curl up and dry.

Yellowing of the older leaves is accompanied by rust-colored blotches.

The leaves curl up, rot sets in, and the older leaves drop.

The flowering is retarded and greatly diminished.

Treat deficiency of potassium by fertilizing with a complete N-P-K fertilizer.

Occasionally, a grower will add potassium directly to the nutrient solution. Organic growers add potassium in the form of soluble potash (wood ashes) mixed with water. Be careful when using wood ash, the pH is normally above 10. Use a pH-lowering mix to bring the pH to around 6.5 before application. Foliar feeding to cure a potassium deficiency is not recommended.

Toxicity occurs occasionally and is difficult to diagnose because it is mixed with the deficiency symptoms of other nutrients. Too much potassium impairs and slows the absorption of magnesium, manganese, and sometimes zinc and iron. Look for signs of toxic-potassium buildup when symptoms of magnesium, manganese, zinc, and iron deficiencies appear.

Treat toxicity by flushing the growing medium of affected plants with a very mild and complete fertilizer. Severe problems require that more water be flushed through the growing medium. Flush with a minimum of three times the volume of water for the volume of the growing medium.



Early stage of K deficiency.



Progression of K deficiency.



Later stage of K deficiency.

Secondary Nutrients

The secondary nutrients—magnesium, calcium, and sulfur—are also used by the plants in large amounts. Rapid-growing indoor marijuana crops are able to process more secondary nutrients than most general-purpose fertilizers are able to supply. Many growers opt to use high quality two- and three-part hydroponic fertilizers to supply all necessary secondary and trace elements. But be careful, these three nutrients may be present in high levels in the ground water. It is important to consider these values when adding nutrient supplements. If growing in a soil or soilless mix with a pH below 7 such as Peat-Lite, incorporating one cup of fine (flour) dolomite lime per gallon of medium ensures adequate supplies of calcium and magnesium.

Macronutrients are the elements that the plants use most. The fertilizers usually show nitrogen (N), potassium (P), phosphorous (K) as (N-P-K) percentages in big numbers on the front of the package. They are always listed in the same N-P-K order. These nutrients must always be in an available form to supply marijuana with the building blocks for rapid growth.

Magnesium (Mg) - mobile

Practical Information: Marijuana uses a lot of magnesium, and deficiencies are common, especially in acidic (pH below 7) soils. Adding dolomite lime to acidic potting soils before planting will stabilize the pH, plus it will add magnesium and calcium to the soil. Add Epsom salts with each watering to correct magnesium deficiencies, if no dolomite was added when planting. Use Epsom salts designed specifically for plants rather than the supermarket-type.

Technical Information: Magnesium is found as a central atom in every chlorophyll molecule, and it is essential to the absorption of light energy. It aids in the utilization of nutrients. Magnesium helps enzymes make carbohydrates and sugars that are later transformed into flowers. It also neutralizes the soil acids and toxic compounds produced by the plant.

Deficiency: Magnesium deficiency is common

indoors. The lower leaves, and later the middle leaves, develop yellow patches between dark, green veins. Rusty-brown spots appear on the leaf margins, tips, and between the veins, as the deficiency progresses. The brownish leaf tips usually curl upward before dying. The entire plant could discolor in a few weeks, and if severe, turn a yellow-whitish tinge before browning and dying. A minor deficiency will cause little or no problem with growth. However, minor deficiencies escalate and cause a diminished harvest as flowering progresses. Most often, magnesium is in the soil but is unavailable to the plant because the root environment is too wet and cold or acidic and cold. Magnesium is also bound in the soil if there is an excess of potassium, ammonia (nitrogen), and calcium (carbonate). Small root systems are also unable to take in enough magnesium to supply heavy demand. A high EC slows the water evaporation and will also diminish magnesium availability.



Early stage of Mg deficiency.

Progression of deficiency symptoms at a glance:

No deficiency symptoms are visible during the first three to four weeks.

In the 4th to the 6th week of growth, the first signs of deficiency appear. Interveinal yellowing and irregular rust-brown spots appear on older and middle-aged leaves. Younger leaves remain healthy.

Leaf tips turn brown and curl upward as the deficiency progresses.



Progression of Mg deficiency.



Later stage of Mg deficiency.

Rust-brown spots multiply and interveinal yellowing increases.

Rust-brown spots and yellowing progress, starting at the bottom and advancing to the top of the entire plant.

Younger leaves develop rust-colored spots and interveinal yellowing.

The leaves dry and die in extreme cases.

Treat deficiency by watering with two teaspoons of Epsom salts (magnesium sulfate) per gallon of water. For fast results, spray the foliage with a 2 percent solution of Epsom salts. If the deficiency progresses to the top of the plant, it will turn green there first. In four to six days, it will start moving down the plant, turning lower leaves progressively more green. Continue a regular watering schedule with Epsom salts until the symptoms totally disappear. Adding Epsom salts regularly is not necessary when the fertilizer contains available magnesium. Use a foliar spray of Epsom salts for a fast cure. Another option is to apply magnesium sulfate monohydrate in place of Epsom salts. Add fine dolomite lime to soil and soilless mix to add a consistent supply of both calcium and magnesium over the long term. Always use the finest dolomite available.

Control the room and root-zone temperatures, humidity, pH, and EC of the nutrient solution. Keep root zone and nutrient solution at 70 to 75°F (21-24°C). Keep ambient air temperature at 75°F (21°C) day and 65°F (18°C) night. Use a complete fertilizer with an adequate amount of magnesium. Keep the soil pH above 6.5, the hydroponic pH above 5.5, and reduce high EC for a week.

The extra magnesium in the soil is generally not harmful, but it can inhibit calcium uptake. Signs of excess magnesium are described below.

Toxicity: Magnesium toxicity is rare and difficult to discern with the naked eye. If extremely toxic, the magnesium develops a conflict with other fertilizer ions, usually calcium, especially in hydroponic nutrient solutions. The toxic buildup of magnesium in soil that is able to grow marijuana is uncommon.

Calcium (Ca) -immobile

Practical Information: Cannabis requires nearly as much calcium as other macronutrients. Avert deficiencies in the soil and in most soilless mixes by adding fine dolomite lime or using soluble-hydroponic fertilizers containing adequate calcium.

Technical Information: Calcium is fundamental to cell manufacturing and growth. Calcium is necessary to preserve membrane permeability and cell integrity, which ensures proper flow of nitrogen and sugars. It stimulates enzymes that help build strong cell and root walls. Cannabis must have some calcium at the growing tip of each root.

Deficiency of calcium is somewhat uncommon indoors, but not uncommon in fiber hemp. Frequently, plants can process more calcium than is available. It also washes out of the leaves that are sprayed with water. Deficiency signs may be difficult to detect. They start with weak stems, very dark green foliage, and exceptionally slow growth. Young leaves are affected, and they show the signs first. Severe calcium deficiency causes new, growing shoots to develop yellowish to purple hues and to disfigure before shriveling up and dying; bud development is inhibited, the plants are stunted, and harvest is diminished. Growing tips could show signs of calcium deficiency if the humidity is maxed out. At 100 percent humidity, the stomata close, which stops the transpiration to protect the plant. The calcium that is transported by transpiration becomes immobile.

Treat deficiencies by dissolving one-half teaspoon of hydrated lime per gallon of water. Water the deficient plants with calcium-dosed water as long as the symptoms persist. Or use a complete hydroponic nutrient that contains adequate calcium. Keep the pH of the growing medium stable.

Progression of deficiency symptoms at a glance:

Slow growth and young leaves turn very dark green.

New growing shoots discolor.

New shoots contort, shrivel, and die.

Bud development slows dramatically.

Toxicity is difficult to see in the foliage. It caus-

es wilting. Toxic levels also exacerbate deficiencies of potassium, magnesium, manganese, and iron. The nutrients become unavailable, even though they are present. If excessive amounts of soluble calcium are applied early in life, it can also stunt the growth. If growing hydroponically, an excess of calcium will precipitate with sulfur in the solution, which causes the nutrient solution to suspend in the water and to aggregate into clumps causing the water to become cloudy (flocculate). Once the calcium and sulfur combine, they form a residue (gypsum $\text{Ca}(\text{SO}_4) \cdot 2(\text{H}_2\text{O})$) that settles to the bottom of the reservoir.

Sulfur (S) - immobile

Practical Information: Many fertilizers contain some form of sulfur, and for this reason, sulfur is seldom deficient. Growers avoid elemental (pure) sulfur in favor of sulfur compounds such as magnesium sulfate. The nutrients combined with sulfur mix better in water.

Technical Information: Sulfur is an essential building block of many hormones and vitamins, including vitamin B₁. Sulfur is also an indispensable element in many plant cells and seeds. The sulfate form of sulfur buffers the water pH. Virtually all ground, river, and lake water contains sulfate. Sulfate is involved in protein synthesis and is part of the amino acid, cystine, and thiamine, which are the building blocks of proteins. Sulfur is essential in the formation of oils and flavors, as well as for respiration and the synthesis and breakdown of fatty acids. Hydroponic fertilizers separate sulfur from calcium in an "A" container and a "B" container. If combined in a concentrated form, sulfur and calcium will form crude, insoluble gypsum (calcium sulfate) and settle as residue to the bottom of the tank.

Deficiency: Young leaves turn lime-green to yellowish. As shortage progresses, leaves yellow interveinally and lack succulence. Veins remain green, and leaf stems and petioles turn purple. Leaf tips can burn, darken, and hook downward. According to literature, youngest leaves should yellow first. But Mauk from Canna Coco in the Netherlands, who has conducted detailed scientific experiments with nutrients, says, "We have repeatedly noticed that the symptoms were

most obvious in the older leaves." Sulfur deficiency resembles a nitrogen deficiency. Acute sulfur deficiency causes elongated stems that become woody at the base.

Sulfur deficiency occurs indoors when the pH is too high or when there is excessive calcium present and available.

Progression of deficiency symptoms at a glance:

Similar to nitrogen deficiency: older leaves turn a pale green.

Leaf stems turn purple and more leaves turn pale green.

Entire leaves turn pale yellow.

Interveinal yellowing occurs.

Acute deficiency causes more and more leaves to develop purple leaf stems and yellow leaves.

Treat deficiency by fertilizing with a hydroponic fertilizer that contains sulfur. Lower the pH to 5.5 to 6. Add inorganic sulfur to a fertilizer that contains magnesium sulfate (Epsom salts). Organic sources of sulfur include mushroom composts and most animal manures. Make sure to apply only well-rotted manures to avoid burning the roots.

Toxicity: An excess of sulfur in the soil causes no problems if the EC is relatively low. At a high EC, the plants tend to take up more available sulfur which blocks uptake of other nutrients. Excess sulfur symptoms include overall smaller plant development and uniformly smaller, dark-green foliage. Leaf tips and margins could discolor and burn when severe.

Treat toxicity by flushing the growing medium



Early stage of S deficiency.



Progression of S deficiency.



Later stage of S deficiency.

of affected plants with a very mild and complete fertilizer. Check the pH of the drainage solution. Correct the input pH to 6. Severe problems require more water to be flushed through the growing medium. Flush a minimum of three times the volume of water for the volume of the growing medium.

Micronutrients

Micronutrients, also called *trace elements* or *trace nutrients*, are essential to chlorophyll formation and must be present in minute amounts. They function mainly as catalysts to the plant's process and utilization of other elements. For best results, and to ensure a complete range of trace elements is available, use fertilizers designed for hydroponics. High quality hydroponic fertilizers use food-grade ingredients that are completely soluble and leave no residues. If using an inexpensive fertilizer that does not list a specific analysis for each trace element on the label, it's a good idea to add soluble trace elements in a chelated form. Chelated micronutrients are available in powdered and liquid form. Add and thoroughly mix micronutrients into the growing medium before planting. Micronutrients are often impregnated in commercial potting soils and soilless mixes. Check the ingredients on the bag to ensure that the trace elements were added to the mix. Trace

MICRONUTRIENTS

Zinc, iron, and manganese are the three most common micronutrients found deficient. Deficiencies of these three micronutrients plague many more grow rooms than I had imagined. Often deficiencies of all three occur concurrently, especially when the soil or water pH is above 6.5. Deficiencies are most common in arid climates—Spain, the Southwestern United States, Australia, etc.—with alkaline soil and water. All three have the same initial symptom of deficiency: interveinal chlorosis of young leaves. It is often difficult to distinguish which element—zinc, iron, or manganese—is deficient, and all three could be deficient. This is why treating the problem should include adding a chelated dose of all three nutrients.

elements are necessary in minute amounts but can easily reach toxic levels. Always follow the manufacturer's instructions to the letter when applying micronutrients, because they are easy to over apply.

Zinc (Zn) - mobile

A **chelate** (Greek for *claw*) is an organic molecule that forms a claw-like bond with free electrically charged metal particles. This property keeps metal ions such as zinc, iron, and manganese, etc., soluble in water, and the chelated metal's reactions with other materials is suppressed. Roots take in the chelated metals in a stable, soluble form that is used immediately.

Natural chelates such as humic acid and citric acid can be added to organic soil mixes. Roots and bacteria also exude natural chelates to promote the uptake of metallic elements. Man-made chelates are designed for use in different situations. DTPA is most effective in a pH below 6.5, EDDHA is effective up to a pH of 8, and EDTA chelate is slow to cause leaf burn.

Chelates decompose rapidly in low levels of ultraviolet (UV) light including light produced by HID bulbs and sunlight. Keep chelates out of the light to protect them from rapid decomposition.

Chelate - combining nutrients in an atomic ring that is easy for plants to absorb.

This information was condensed from Canna Products, www.canna.com.

Practical Information: Zinc is the most common micronutrient found deficient in arid climates and alkaline soils.

Technical Information: Zinc works with manganese and magnesium to promote the same enzyme functions. Zinc cooperates with other elements to help form chlorophyll as well as prevent its demise. It is an essential catalyst for most plants' enzymes and auxins, and it is crucial for stem growth. Zinc plays a vital part in sugar and protein production. It is fairly common to find zinc-deficient cannabis. Deficiencies are most common in soils with a pH of 7 or more.

Deficiency: Zinc is the most common micronutrient found deficient. First, younger



Early stage of Zn deficiency.



Progression of Zn deficiency.



Later stage of Zn deficiency.

leaves exhibit interveinal chlorosis, and new leaves and growing tips develop small, thin blades that contort and wrinkle. The leaf tips, and later the margins, discolor and burn. Burned spots on the leaves could grow progressively larger. These symptoms are often confused with a lack of manganese or iron, but when zinc deficiency is severe, new leaf blades contort and dry out. Flower buds also contort into odd shapes, turn crispy dry, and are often hard. A lack of zinc stunts all new growth including buds.

Progression of deficiency symptoms at a glance:

Interveinal chlorosis of young leaves.

New leaves develop thin, wispy leaves.

Leaf tips discolor,

turn dark, and die back.

New growth contorts horizontally.

New bud and leaf growth stops.

Treat zinc-deficient plants by flushing the growing medium with a diluted mix of a complete fertilizer containing chelated trace elements, including zinc, iron, and manganese. Or add a quality-brand hydroponic micronutrient mix containing chelated trace elements.

Toxicity: Zinc is extremely toxic in excess. Severely toxic plants die quickly. Excess zinc interferes with the iron's ability to function properly and causes an iron deficiency.

Manganese (Mn) - immobile

Practical Information: Manganese deficiency is relatively common indoors.

Technical Information: Manganese is engaged in the oxidation-reduction process associated with the photosynthetic electron transport. This element activates many enzymes and plays a fundamental part in the chloroplast membrane system. Manganese assists nitrogen utilization along with iron in chlorophyll production.

Deficiency: Young leaves show symptoms first. They become yellow between veins (interveinal chlorosis), and the veins remain green. Symptoms spread from younger to older leaves as the deficiency progresses. Necrotic (dead) spots develop on severely affected leaves which become pale and fall off; overall plant growth is stunted, and maturation may be prolonged. Severe deficiency looks like a severe lack of magnesium.

Treat deficiency: Lower the pH, leach the soil, and add a complete, chelated micronutrient formula.

Progression of deficiency symptoms at a glance:

Interveinal chlorosis of young leaves forms.

Interveinal chlorosis of progressively older leaves forms.

Dead spots develop on acutely affected leaves.

Toxicity: Young and newer growth develop chlorotic, dark orange to dark, rusty-brown mottling on the leaves. Tissue damage shows on young leaves before progressing to the older



Early stage of Mn deficiency.



Progression of Mn deficiency.



Later stage of Mn Deficiency.

leaves. Growth is slower, and overall vigor is lost. Toxicity is compounded by low humidity. The additional transpiration causes more manganese to be drawn into the foliage. A low pH can cause toxic intake of manganese. An excess of manganese causes a deficiency of iron and zinc.

Iron (Fe) - immobile

Practical Information: Iron is available in a soluble chelated form that is immediately available for absorption by the roots. Deficiency indoors is common in alkaline soils.

Technical Information: Iron is fundamental to the enzyme systems and to transport electrons during photosynthesis, respiration, and

chlorophyll production. Iron permits plants to use the energy provided by sugar. A catalyst for chlorophyll production, iron is necessary for nitrate and sulfate reduction and assimilation. Iron colors the earth from brown to red, according to concentration. Plants have a difficult time absorbing iron. Acidic soils normally contain adequate iron for cannabis growth.

Deficiency: Iron deficiencies are common when the pH is above 6.5 and uncommon when the pH is below 6.5. Symptoms may appear during rapid growth or stressful times and disappear by themselves. Young leaves are unable to draw immobile iron from older leaves, even though it is present in the soil. The first

symptoms appear on the smaller leaves as veins remain green and areas between the veins turn yellow. Interveinal chlorosis starts at the opposite end of the leaf tip: the apex of the leaves attached by the petiole. Leaf edges can turn upward as the deficiency progresses. Leaves fall off in severe cases. Iron deficiency is sometimes traced to an excess of copper. See "Copper."

Progression of deficiency symptoms at a glance:

Younger leaves and growing shoots turn pale green and progress to yellow between the veins starting at the petiole but the veins remain green.

More and more leaves turn yellow and develop interveinal chlorosis.

Larger leaves finally yellow and develop interveinal chlorosis.

In acute cases, leaves develop necrosis and drop.

Treat iron deficiencies

by lowering the soil pH to 6.5 or less. Avoid fertilizers that contain excessive amounts of manganese, zinc, and copper, which inhibit iron uptake. High levels of phosphorus compete with the uptake of iron. Improve the drainage; excessively wet soil holds little oxygen to spur iron uptake. Damaged or rotten roots also lower iron uptake. Increase root-zone temperature. Apply chelated iron in liquid form to root zone. Chelates are decomposed by light and must be thoroughly mixed with the grow-



Early stage of Fe deficiency.



Progression of Fe deficiency.



Later stage of Fe deficiency.

ing medium to be effective. Exposing the nutrient solution to light causes depleted iron. Sterilizing the nutrient solution with UV light causes iron to precipitate. Leaves should green up in four or five days. Complete, balanced, hydroponic nutrients contain iron, and deficiencies are seldom a problem. Organic sources of iron, as well as chelates, include cow, horse, and chicken manure. Use only well-rotted manures to avoid burning plants.

Toxicity: Excess of iron is rare. High levels of iron do not damage cannabis, but it can interfere with phosphorus uptake. An excess of iron causes the leaves to turn bronze accompanied by small, dark brown leaf spots. If iron chelate is over applied, it will kill the plant in a few days.

Treat excess iron by leaching plants heavily.

The following group of micronutrients is seldom found deficient. Avoid deficiencies by using a high-quality hydroponic fertilizer that contains chelated micronutrients.

Boron (B) - immobile

Practical Information: Usually causes no problems, but boron must be available during the entire life of a plant.

Technical Information: Boron deficiencies seldom occur indoors. Boron is still somewhat of a biochemical mystery. We know that boron helps with calcium uptake and numerous plant functions. Scientists have collected evidence to suggest boron helps with synthesis, a base for the formation of nucleic acid (RNA uracil) formation. Strong evidence also supports boron's role in cell division, differentiation, maturation, and respiration as well as a link to pollen germination.

Deficiency: Stem tip and root tip grow abnormally. Root tips often swell, discolor, and stop elongating. Growing shoots look burned and may be confused with a burn from being too close to the HID light. First leaves thicken and become brittle, top shoots contort and/or turn dark, which is later followed by progressively lower-growing shoots. When severe, growing tips die, and leaf margins discolor and die back in places. Necrotic spots develop between leaf veins. Root steles (insides) often become

mushy—perfect hosts for rot and disease. Deficient leaves become thick, distorted, and wilted with chlorotic and necrotic spotting.

Treat boron-deficient plants with one teaspoon of boric acid per gallon of water. You can apply this solution as a soil drench to be taken up by the roots, or apply hydroponic micronutrients containing boron. Hydroponic gardeners should keep boron dosage below 20 parts per million (ppm), because boron quickly becomes toxic if it is concentrated in the solution.

Toxicity: Leaf tips yellow first, and as the toxic conditions progress, leaf margins become necrotic toward the center of the leaf. After the leaves yellow, they fall off. Avoid using excessive amounts of boric acid-based insecticides.

Chlorine (Chloride) (Cl) - immobile

Practical Information: Chloride is found in many municipal water systems. Cannabis tolerates low levels of chlorine. It is usually not a component of fertilizers and is almost never deficient in gardens that grow cannabis.

Technical Information: Chlorine, in the form of chloride, is fundamental to photosynthesis and cell division in the roots and the foliage. It also increases osmotic pressure in the cells, which open and close the stomata to regulate moisture flow within the plant tissue.

Deficiency: It is uncommon to be deficient. Young leaves pale and wilt, and roots become stubby. As the deficiency progresses, leaves become chlorotic and develop a characteristic bronze color. The roots develop thick tips and become stunted. NOTE: Both severe deficiency and excess of chloride have the same symptoms: bronze-colored leaves.

Treat chlorine deficiencies by adding chlorinated water.

Toxicity: Young leaves develop burned leaf tips and margins. Very young seedlings and clones are the most susceptible to damage. Later, the symptoms progress throughout the plant. Characteristic yellowish-bronze leaves are smaller and slower to develop.

Treat toxic signs of chlorine by letting heavily chlorinated water sit out overnight, stirring occasionally. Chlorine will volatilize and disappear into the atmosphere. Use this water to mix the nutrient solution or to irrigate the garden.

Cobalt (Co) - immobile

Practical Information: This nutrient is seldom mentioned as necessary for plant growth, and most fertilizer labels do not include cobalt. Cobalt is virtually never deficient in indoor cannabis gardens.

Technical Information: Cobalt is necessary for countless beneficial bacteria to grow and flourish. It is also vital for nitrogen absorption. Scientific evidence suggests this element is linked to enzymes needed to form aromatic compounds.

Deficiency: When deficient, the problems with nitrogen availability occur.

Copper (Cu) - immobile

Practical Information: Copper is concentrated in the roots. It is also used as a fungicide.

Technical Information: Copper is a component of numerous enzymes and proteins. Necessary in minute amounts, copper helps with carbohydrate metabolism, nitrogen fixation, and the process of oxygen reduction. It also helps with the making of proteins and sugars.

Deficiency: Copper deficiencies are not rare. Young leaves and growing shoots wilt, leaf tips and margins develop necrosis and turn a dark, copper-gray. Occasionally, an entire copper-deficient plant wilts, drooping even when adequately watered. Growth is slow and the yield decreases. A small deficiency can cause new shoots to die back.

Treat copper deficiency by applying a copper-based fungicide such as copper sulfate. Do not apply if the temperature is above 75°F (24°C) to avoid burning the foliage. Apply a complete hydroponic nutrient that contains copper. Cannabis plants seldom develop a copper deficiency.

Toxicity: Copper, although essential, is extremely toxic to the plant even in minor excess. Toxic levels slow the overall plant growth. As the toxic level climbs, symptoms include interveinal iron chlorosis (deficiency) and stunted growth. Fewer branches grow, and the roots become dark, thick, and slow growing. Toxic conditions accelerate quickly in acidic soils. Hydroponic gardeners must carefully monitor their solution to avoid copper excess.

Treat toxicity: Flush the soil or the growing medium to help expel the excess copper. Do not use copper-based fungicides.

Molybdenum (Mb) - immobile

Practical Information: Molybdenum is seldom deficient.

Technical Information: Molybdenum is a part of two major enzyme systems that convert nitrate to ammonium. This essential element is used by cannabis in very small quantities. It is most active in roots and seeds.

Deficiency: This micronutrient is almost never found deficient in cannabis. Deficiency promotes nitrogen shortage. First, the older and middle-aged leaves yellow, and some develop interveinal chlorosis; then the leaves continue to yellow and develop cupped or rolled-up margins as the deficiency progresses. Acute symptoms cause the leaves to become severely twisted, die, and drop. Overall growth is stunted. Deficiencies are worst in acidic soils.

Toxicity: Excess is uncommon in marijuana gardens. An excess of molybdenum causes a deficiency of copper and iron.

Silicon - (Si)

Practical Information: Silicon is readily available in most soils, water, and as far as I know, it does not cause cannabis any complications due to deficiencies or excesses.

Technical Information: Silicon is absorbed by the plants as silicic acid. Silicon assists in keeping iron and manganese levels consistent. It is found mainly in the epidermal cell walls where it collects in the form of hydrated amorphous silica. It also accumulates in the walls of other cells. Adequate and soluble silicon guarantees stronger cell walls that resist pest attacks and increase heat and drought tolerance.

Deficiency: A lack of silicon has been proven to decrease yields of some fruits and cause new leaves to deform.

Excess: Never heard of a problem.

NOTE: Pests and diseases have a difficult time penetrating the plants that are sprayed with a silicon-based repellent/insecticide.

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Fertilizers show the N-P-K in big letters on the front of the package.

Nickel - (Ni)

Enzymes require nickel to break down and use the nitrogen from the urea. It is also essential to iron absorption. Seldom deficient and subtly mixed with other nutrient deficiencies, most commonly nitrogen.

Sodium - (Na)

This is one of the problem elements. A little bit will go a long way! Sodium is taken up by the roots very quickly and in small amounts (50 ppm). It can block enough other nutrients causing severe deficiencies to result. When mixed with chlorine, it turns into table salt, which is the worst possible salt to put on the plants. Be very careful to measure your input water to ensure that it contains less than 50 ppm sodium. The less sodium in the solution, the better.

Fluoride - (F)

Some water systems are abundant with fluoride. If concentrated, fluoride can become toxic. I have yet to see fluoride toxicity or deficiency cause problems in an indoor grow room.

Fertilizers

The goal of fertilizing is to supply the plants with the proper amounts of nutrients for vigorous growth, without creating toxic conditions by overfertilizing. A 2-gallon (8 L) container full of rich, fertile potting soil will supply all the necessary nutrients for the first month of growth, but the development might be slow. After the roots have absorbed most of the available nutrients, more must be added to sustain vigorous growth. Unless fortified, soilless mixes require fertilization from the start. I like to start

fertilizing fortified soilless mixes after the first week or two of growth. Most commercial soilless mixes are fortified with trace elements.

Marijuana's metabolism changes as it grows and so do its fertilizer needs. During germination and seedling growth, intake of phosphorus is high. The vegetative growth stage requires larger amounts of nitrogen for green-leaf growth, and phosphorus and potassium are also necessary in substantial levels. During this leafy and vegetative growth stage, use a *general purpose* or a *grow* fertilizer with high nitrogen content. In the flowering stage, nitrogen takes a backseat to potassium, phosphorus, and calcium intake. Using a *super bloom* fertilizer with less nitrogen and more potassium, phosphorus, and calcium promotes fat, heavy, dense buds. Cannabis needs some nitrogen during flowering, but very little. With no nitrogen, buds do not develop to their full potential.

Now we come to the confusing part about the *guaranteed analysis* of commercial fertilizer mixes. Federal and state laws require nutrient concentrations to appear prominently on the face of the fertilizer packages, even though the accuracy of the values is dubious.

Do you think the N-P-K numbers on the label give the percentages of nitrogen, phosphorous, and potassium? Well, yes and no. The scale measures nutrients with different scales. Nitrogen is listed as *total combined elemental*. Most hydroponic fertilizers break nitrogen into slow-acting nitrate (NO_3) and ammonium (NH_4). Phosphoric anhydride (P_2O_5) is listed as the form of phosphorus, but this figure understates phosphorus content by 44 percent. It gets worse! The balance (56 percent) of the phosphorus molecule is comprised of oxygen. Twenty percent P_2O_5 is 8.8 percent actual phosphorous. Potassium (K) is listed in the potash form of potassium oxide (K_2O) of which 83 percent of the stated value is actually elemental potassium.

The rest of the mineral nutrients are listed in their elemental form that represents the actual content. Most often, the mineral elements used in the fertilizer formulas are listed in chemical compounds on the label. Look at the fertilizer labels to ensure that the elements, especially trace elements, are chelated and readily available for root absorption. Also, be careful about having too much sodium in your water/nutrient solution. The sodium will block potassium and several other nutrients, causing deficiencies and slow growth.

Nutrients in the United States are measured in parts-per-million (ppm), even though they are expressed as a percentage concentration on the label. The ppm scale is simple and finite—almost. The basics are simple: one part per million is one part of 1,000,000, so divide by one million to find parts per million. To convert percentages into ppm, multiply by 10,000 and move the decimal four (4) spaces to the right. For example: 2 percent equals 20,000 ppm. For more information on ppm and Electrical Conductivity, see Chapter Twelve, "Hydroponic Gardening."

Fertilizers are either water-soluble or partially soluble (gradual-release). Both soluble and

gradual-release fertilizers can be organic or chemical.

These are the suggested soluble-salts fertilizer recommendations for indoor cannabis cultivation. The values are expressed in parts per million.

Chemical Fertilizers

The diversity of hydroponic fertilizers is amazing. Local shop owners know which ones work best in the local climate and water. Local store-owners know a lot about the local water and the growers' needs. They are in a perfect position to develop their own nutrient solution or adapt one that works well with their water. A few manufacturers do not do their homework and make bad nutrients. Most manufacturers are conscious and manufacture excellent fertilizers. As always, read the entire fertilizer label and follow the directions.

Soluble-chemical fertilizers are an excellent choice for indoor container cultivation. Soluble fertilizers dissolve in water and are easy to control, and they can be easily added or washed (leached) out of the growing medium. Control the exacting amounts of nutrients available to the plants in an available form with water-soluble fertilizers. The soluble fertilizer may be applied in a water solution onto the soil. In general, high-quality hydroponic fertilizers that use completely soluble food-grade nutrients are the best value. Avoid low-quality fertilizers that do not list all necessary micronutrients on the label.

Chemical granular fertilizers work well but can easily be over-applied, creating toxic soil. They are almost impossible to leach out fast enough to save the plant.

Osmocote™ chemical fertilizers are time release and are used by many nurseries because they are easy to apply and only require one application every few months. Using this type of fertilizer may be convenient, but exacting control is lost. They are best suited for ornamental, containerized plants where labor costs and uniform growth are the main concerns.

Organic Fertilizers

Organically grown cannabis has a sweeter taste, but implementing an organic indoor gar-

Element	Limits	Average
Nitrogen	150 – 1000	250
Calcium	100 – 150	200
Magnesium	50 – 100	75
Phosphorus	50 – 100	80
Potassium	100 – 400	300
Sulfur	200 – 1000	400
Copper	0.1 – 0.5	0.5
Boron	0.5 – 5.0	1.0
Iron	2.0 – 10	5.0
Manganese	0.5 – 5.0	2.0
Molybdenum	0.01 – 0.05	0.02
Zinc	0.5 – 1.0	0.5

These are the suggested soluble-salts fertilizer recommendations for indoor cannabis cultivation. The values are expressed in parts per million.

den requires horticultural know-how. The limited soil, space, and the necessity for sanitation must be considered when growing organically. Outdoors, organic gardening is easy because all of the forces of nature are there for you to seek out and harness. Indoors, few of the natural phenomena are free and easy. Remember, you are Mother Nature and must create everything! The nature of growing indoors does not lend itself to long-term organic gardens, but some organic techniques have been practiced with amazing success.

Most indoor organic gardens use potting soil high in worm castings, peat, sand, manure, leaf mold, compost, and fine dolomite lime. In a container, there is little space to build the soil by mixing all kinds of neat composts and organic nutrients to cook down. Even if it were possible to build the soil in a container, it would take months of valuable growing time and it could foster bad insects, fungi, etc. It is easier and safer to throw old, depleted soil outdoors, and start new plants with fresh organic soil.

Organic nutrients, manure, worm castings, blood and bone meal, etc., all work very well to increase the soil nutrient content, but nutrients are released and available at different rates. The nutrient availability may be tricky to calculate, but it is somewhat difficult to over-apply organic fertilizers. Organic nutrients seem to be more consistently available when used in combination with one another. Usually, growers use a mix of about 20 percent worm castings with other organic agents to get a strong, readily available nitrogen base. They fertilize with bat guano, the organic super bloom, during flowering.

An indoor garden using raised beds allows true organic methods. The raised beds have enough soil to hold the nutrients, promote organic activity, and when managed properly, ensure a constant supply of nutrients. The raised beds must have enough soil mass to promote heat and fundamental organic activity.



Several common chemical fertilizers from the hydroponic industry.

Outdoor organic gardens are easy to implement and maintain. Using compost tea, manures, bulky compost, and other big, smelly things is much easier outdoors.

Organic Teas

Compost teas not only contain soluble organic nutrients diluted in water, but they support a potent elixir that is loaded with beneficial microbes that fight off pests and diseases. For example, a quarter teaspoon of a well-made compost tea holds more than a billion bacteria and at least 15 feet of fungi strands! A good compost tea also contains thousands of different species of protozoa, nematodes, and mycorrhizal fungi.

Disease-causing organisms are unable to compete with beneficial bacteria and fungi. Beneficial bacteria also work to break down plant residues and toxic materials, plus they improve soil structure and water-holding ability.

The best teas are made from well-rotted compost, because it contains a complex collection of microbes and nutrients. Just make sure the compost pile has heated to 135°F (52°C) for at least 3 days to ensure it is free of most diseases. You can usually buy quality compost at the local nursery. If using manure, make sure it has been well-composted.

You can brew the tea in a 5-gallon (19 L) bucket. Add about a gallon (3.8 L) of rotted compost or manure to 4 gallons (15 L) of water. Stir well, and let the mix sit for several days. You can also put sifted compost into a nylon stocking, and

submerge it in the bucket. To stir, simply bounce the stocking around in the water. Stir the mixture gently several times a day to integrate oxygen and remove microbes from the compost. Adequate oxygen keeps the brew fresh. If it starts to smell foul, anaerobic bacteria are present. Add fresh water and stir more often. The good aerobic bacteria re-establish as soon as they have an ample supply of oxygen.

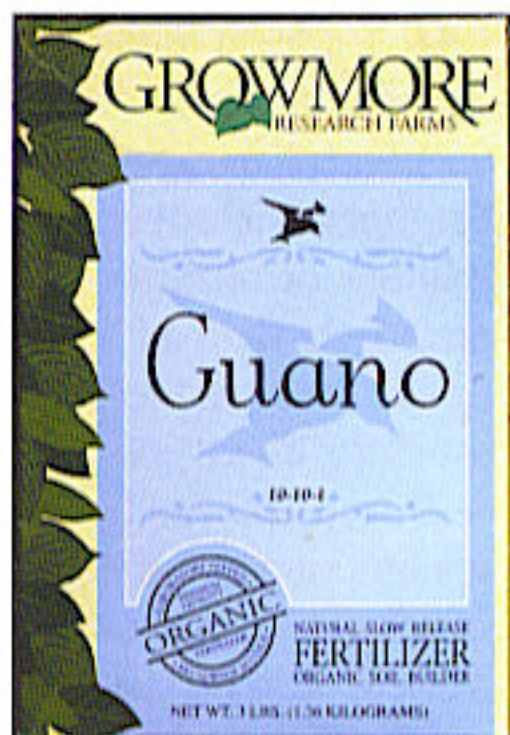
Organic Nutrients Chart

Alfalfa meal has 2.5 percent nitrogen, 5 percent phosphorus, and about 2 percent potash. Outdoor growers use pelletized animal feed as a slow-release fertilizer.

Blood and bone meal are wonderful organic fertilizers, but could transport Mad Cow Disease and other maladies. I can't recommend these with a clear conscience.

Blood (dried or meal) is collected at slaughterhouses, dried, and ground into a powder or meal. It's packed with fast-acting soluble nitrogen (12 to 15 percent by weight), about 1.2 percent phosphorus, and under one-percent potash. Apply carefully because it's easy to burn foliage. We advise avoiding use of any dried blood or blood meal that could carry Mad Cow Disease.

Bone meal is rich in phosphorus and nitrogen. The age and type of bone determine the nutrient content of this pulverized slaughterhouse product. Older bones have higher



Here are just a few of the numerous fertilizers available for cannabis cultivation.

phosphorus content than young bones. Use bone meal in conjunction with other organic fertilizers for best results. Its lime content helps reduce soil acidity and acts fast in well-aerated soil. We advise avoiding any bone meal that could carry Mad Cow Disease.

Raw, unsteamed bone meal contains 2 to 4 percent nitrogen and 15 to 25 percent phosphorus. Fatty acids in raw bone meal retard decomposition. We advise avoiding any bone meal that could carry Mad Cow Disease.

Steamed or cooked bone meal is made from fresh animal bones that have been boiled or steamed under pressure to render out fats. The pressure treatment causes a little nitrogen loss and an increase in phosphorus. Steamed bones are easier to grind into a fine powder, and the process helps nutrients become available sooner. It contains up to 30 percent phosphorus and about 1.5 percent nitrogen. The finer the bone meal is ground, the faster it becomes available.

Cottonseed meal is the leftover by-product of oil extraction. According to the manufacturer, virtually all chemical residues from commercial cotton production are dissolved in the oil and not found in the meal. This acidic fertilizer contains about 7 percent nitrogen, 2.5 percent phosphorus, and 1.5 percent potash. It should be combined with steamed bone meal and seaweed to form a balanced fertilizer blend.

Chicken manure is rich in available nitrogen, phosphorus, potassium, and trace elements. Indoor growers most often prefer to purchase dry, composted chicken manure in a bag. Use it as a top dressing or mix it with the soil before planting. Often chicken manure collected from farms is packed with feathers, which contain as much as 17 percent nitrogen; this is an added bonus. The average nutrient content of wet chicken manure is as follows: N – 1.5%, P – 1.5%, K – 0.5%; and dry chicken manure, N – 4%, P – 4%, K – 1.5%. Both have a full range of trace elements.

Coffee grounds are acidic and encourage

acetic bacteria in the soil. Drip-coffee grounds are the richest, and contain about 2 percent nitrogen and traces of other nutrients. Add this to the compost pile or scatter and cultivate it in. Use it as topdressing, but in moderation, because it is very acidic.

Compost tea is used by many organic gardeners as the only source of fertilizer. Comfrey is packed with nutrients, and many gardeners grow it just to make compost tea.

Cow manure is sold as steer manure, but it is often collected from dairy herds. Gardeners have used cow manure for centuries, and this has led to the belief that it is a good fertilizer as well as a soil amendment. Steer manure is most valuable as mulch and a soil amendment. It holds water well and maintains fertility for a long time. The nutrient value is low, and it should not be relied upon for the main source of nitrogen. The average nutrient content of cow manure is N – 0.6%, P – 0.3%, K – 0.3%, and a full range of trace elements. Apply at the rate of 25 to 30 pounds per square yard.

Diatomaceous earth, the fossilized skeletal remains of fresh and saltwater diatoms, contains a full range of trace elements, and it is a good insecticide. Apply it to the soil when cultivating or as a topdressing.

Dolomite lime adjusts and balances the pH and makes phosphates more available. Generally applied to sweeten or de-acidify the soil. It consists of calcium and magnesium, and is sometimes listed as a primary nutrient, though it is generally referred to as a secondary nutrient.

Feathers and feather meal contain from 12 to 15 percent nitrogen that is released slowly. Feathers included in barnyard chicken manure or obtained from slaughterhouses are an excellent addition to the compost pile or as a fertilizer. Feathers are steamed under pressure, dried, and ground into a powdery feather meal. Feather meal contains slow-release nitrogen of about 12.5 percent.

Fish meal is made from dried fish ground into a meal. It is rich in nitrogen (about 8 percent) and contains around 7 percent phos-

phoric acid and many trace elements. It has an unpleasant odor, causing it to be avoided by indoor growers. It is a great compost activator. Apply it to the soil as a fast-acting top-dressing. To help control odor, cultivate it into the soil or cover it with mulch after applying. Always store it in an air-tight container, so it will not attract cats, dogs, or flies. Fish meal and fish emulsion can contain up to 10 percent nitrogen. The liquid generally contains less nitrogen than the meal. Even when deodorized, the liquid form has an unpleasant odor.

Fish emulsion, an inexpensive soluble liquid, is high in organic nitrogen, trace elements, and some phosphorus and potassium. This natural fertilizer is difficult to over-apply, and it is immediately available to the plants. Even deodorized fish emulsion smells like dead fish. Inorganic potash is added to the fish emulsion by some manufacturers and is semi-organic.

Goat manure is much like horse manure but more potent. Compost this manure and treat it as you would horse manure.

Granite dust or granite stone meal contains up to 5 percent potash and several trace elements. Releasing nutrients slowly over several years, granite dust is an inexpensive source of potash and does not affect soil pH. Not recommended indoors because it is too slow acting.

Greensand (glaucomite) is an iron-potassium silicate that gives the minerals in which it occurs a green tint. It is mined from ancient New Jersey-seabed deposits of shells and organic material rich in iron, phosphorus, potash (5 to 7 percent), and numerous micronutrients. Some organic gardeners do not use Greensand because it is such a limited resource. Greensand slowly releases its treasures in about four years. This is too slow acting for indoor gardens.

Guano (bat) consists of the droppings and remains of bats. It is rich in soluble nitrogen, phosphorus, and trace elements. The limited supply of this fertilizer—known as the soluble organic super bloom—makes it somewhat

expensive. Mined in sheltered caves, guano dries with minimal decomposition. Bat guano can be thousands of years old. Newer deposits contain high levels of nitrogen and can burn foliage if applied too heavily. Older deposits are high in phosphorus

and make an excellent flowering fertilizer. Bat guano is usually powdery and is used any time of year as top dressing or diluted in a tea. Do not breathe the dust when handling it, because it can cause nausea and irritation.

Guano (sea bird) is high in nitrogen and other nutrients. The Humboldt Current, along the coast of Peru and northern Chile, keeps the rain from falling, and decomposition of the guano is minimal. South American guano is the world's best guano. The guano is scraped off rocks of arid sea islands. Guano is also collected from many coastlines around the world, so its nutrient content varies.

Gypsum (hydrated calcium sulfate) is used to lower the soil pH, and it improves drainage and aeration. It is also used to hold or slow the rapid decomposition of nitrogen. This is seldom used indoors.

Hoof and horn meal is an excellent source of slow-release nitrogen. Fine-ground horn meal makes nitrogen available quicker and has few problems with fly maggots. Soil bacteria must break it down before it is available to the roots. Apply it two to three weeks before planting. It remains in the soil for six months or longer. Hoof and horn meal contains from 6 to 15 percent nitrogen and about 2 percent phosphoric acid. We advise avoiding use of any dried blood or



Bat guano has transformed into the organic super bloom fertilizer.

bone meal that could carry Mad Cow Disease.

Horse manure is readily available from horse stables and racetracks. Use horse manure that has straw or peat for bedding, since wood shavings could be a source of plant disease. Compost horse manure for two months or longer before adding it to the garden. The composting process kills weed seeds, and it will make better use of the nutrients. Straw bedding often uses up much of the available nitrogen. Nutrient content of horse manure is N – 0.6%, P – 0.6%, K – 0.4%, and a full range of trace elements.

Kelp is the *Cedilla* of trace minerals. Kelp should be deep-green, fresh, and smell like the ocean. Seaweed contains 60 to 70 trace minerals that are already chelated (existing in a form that's water soluble and mobile in the soil). Check the label to ensure all elements are not cooked out. See Seaweed below.

Oyster shells are ground and normally used as a calcium source for poultry. They contain up to 55 percent calcium and traces of many other nutrients that release slowly. Not practical to use indoors because they break down too slowly.

Paper ash contains about 5 percent phosphorus and over 2 percent potash. It is an excellent water-soluble fertilizer, but do not apply in large doses, because the pH is quite high. Paper ash is also full of toxic inks.

Pigeon manure has a very high concentration of nitrogen but is difficult to find. It can be used in the same fashion as chicken manure.

Rabbit manure is also excellent fertilizer but can be difficult to find in large quantities. Use rabbit manure as you would chicken or pigeon manure. According to John McPartland, rabbit poop is the best. Bunnies rule!

Potash rock supplies up to 8 percent potassium and may contain many trace elements. It releases too slowly to be practical indoors.

Rock phosphate (hard) is a calcium or lime-

based phosphate rock that is finely ground to the consistency of talcum powder. The rock powder contains over 30 percent phosphate and a menagerie of trace elements, but it is available very, very slowly.

Colloidal phosphate (powdered or soft phosphate) is a natural clay phosphate deposit that contains just over 20 percent phosphorus (P_2O_5), calcium, and many trace elements. It yields only 2 percent phosphate by weight the first few months.

Seaweed meal and/or kelp meal is harvested from the ocean or picked up along the beaches, cleansed of salty water, dried, and ground into a powdery meal. It is packed with potassium (potash), numerous trace elements, vitamins, amino acids, and plant hormones. The nutrient content varies according to the type of kelp and growing conditions. Seaweed meal is easily assimilated by the plants, and contributes to soil life, structure, and nitrogen fixation. It may also help the plants resist many diseases and withstand light frosts. Kelp meal also eases transplant shock.

Seaweed (liquid) contains nitrogen, phosphorus, potash, all necessary trace elements in a chelated form, as well as plant hormones. Apply diluted solution to the soil for a quick cure of nutrient deficiencies. Liquid seaweed is also great for soaking seeds and, dipping cuttings and bare roots before planting.

Sheep manure is high in nutrients and makes a wonderful tea. The average nutrient content is: N – 0.8%, P – 0.5%, K – 0.4%, and a full range of trace elements. Sheep manures contain little water and lots of air. They heat up readily in a compost pile. Cow and pig manures are cold because they hold a lot of water and can be compacted easily, squeezing out the air.

Shrimp & crab wastes contain relatively high levels of phosphorus.

Sulfate of potash is normally produced chemically by treating rock powders with sulfuric acid, but one company, Great Salt Lake Minerals and Chemicals Company,

produces a concentrated natural form. The sulfate of potash is extracted from the Great Salt Lake.

Swine manure has a high nutrient content but is slower acting and wetter (more anaerobic) than cow and horse manure. The average nutrient content of pig manure is: N – 0.6%, P – 0.6%, K – 0.4%, and a full range of trace elements.

Wood ashes (hardwood) supply up to 10 percent potash, and softwood ashes contain about 5 percent. Potash leaches rapidly. Collect the ash soon after burning, and store in a dry place. Apply in a mix with other fertilizers at the rate of one-quarter cup per 3-gallon pot. The potash washes out of the wood ash quickly and can cause compacted, sticky soil. Avoid using alkaline wood ashes in soil with a pH above 6.5.

Worm castings are excreted, digested humus and other (decomposing) organic matter that contain varying amounts of nitrogen as well as many other elements. They are an excellent source of non-burning soluble nitrogen and an excellent soil amendment that promotes fertility and structure. Mix with the potting soil to form a rich, fertile blend. Pure worm castings look like coarse graphite powder and are heavy and dense. Do not add more than 20 percent worm castings to any mix. They are so heavy that root growth can be impaired. Worm castings are very popular and easier to obtain at commercial nurseries.

Note: The nutrients in organic fertilizers may vary greatly depending upon source, age, erosion, climate, etc. For exact nutrient content, consult the vendor's specifications.



Fill a nylon stocking with sifted, well-rotted compost and soak in a bucket for a few days to make a potent fertilizer and plant elixir.

Foodweb, Inc., compares some commercial tea makers, including a bio-blender used in a 5-gallon bucket, 100-, and 500-gallon brewers. The book includes recipes for high bacteria, high fungal, and high mycorrhizal teas. Take a look at the super-compost tea makers at www.soil_soup.com.

Mixing Fertilizers

Always read the entire label, and follow the directions. To mix, dissolve the powder and the crystals into a little warm water, and make sure it is totally dissolved before adding the balance of the tepid water. This will ensure that the fertilizer and the water mix evenly. Liquid fertilizers can be mixed directly with water.

Containers have very little growing medium in which to hold the nutrients, and toxic salt buildup may become a problem. Follow dosage instructions to the letter. Adding too much fertilizer will not make the plants grow faster. It could change the chemical balance of the soil, supply too much of a nutrient, or lock in other nutrients making them unavailable to the plant.

Fertilizer Application

Some varieties can take high doses of nutrients, and other strains grow best with a minimum of supplemental fertilizer. See the chart at

Dilute the tea at the rate of 1 to 5 with water. Add more water to the same bucket, and continue to brew 3 to 4 more batches before starting a new batch.

Make super tea by gently agitating and oxygenating the soup. This will supercharge the tea and add 10 to 100 times more microbes than regular compost tea. *The Compost Tea Brewing Manual* by Dr. Elaine R. Ingham of Soil

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The gods
must be crazy

To get an idea of which strains need a little or a lot of fertilizer, I asked Alan from Sensi Seeds and Henk from Dutch Passion their thoughts. To learn the exact best way to fertilize specific strains, you may need to contact the company that sold you the seeds.

Start with an EC of 1.6 and build it up as needed. The absolute maximum EC is 2.3.

Strains which require high doses of fertilizer:

All the Indicas, with the possible exception of Hindu Kush (a landrace, with less vigor and not as nutrient-hungry as hybrid Indicas). In this case, 'more fertilizer means using the high end of the recommended dosage, not exceeding it.

Twilight, Green Spirit, Khola, Hollands Hope.

Passion#1, Shaman within an EC range of 1.6-2.3

Strains which require medium doses of fertilizer:

Skunk#1, Trance, Voodoo, Sacra Frasca, Cal. Orange, Delta 9, Skunk Passion.

Blueberry, Durban Poison, Purple#1, Purple Star, Skunk#1, Super Haze, Ultra Skunk, Orange Bud, White Widow, Power Plant and Euforia within an EC range of 1.6-2.3

Strains which require low doses of fertilizer:

All the Sativa hybrids, with the exceptions of Silver Pearl, Marley's Collie and Fruity Juice (Sativa hybrids, but with a heavy, Indica-dominant bud pattern). In this case, less fertilizer means using the low end of the recommended dosage. Northern Lights #5 x Haze has more open buds in growth pattern, but a lot of floral bulk by weight, so may need normal to slightly higher levels of nutrient.

Isis, Flo, Dolce Vita, Dreamweaver Masterkush, Oasis, Skywalker and Hempstar within an EC range of 1.6-2.3. Mazar needs a higher EC during weeks 3 to 5 to prevent early yellowing of the leaves.

left for recommendations on fertilizing a few varieties. Many fertilizer programs are augmented with different additives that expedite nutrient uptake.

Determine if the plants need to be fertilized: make a visual inspection, take an N-P-K soil test, or experiment on test plants. No matter which method is used, remember, plants in small containers use available nutrients quickly and need frequent fertilizing, while plants in large planters have more soil, supply more nutrients, and can go longer between fertilizing.

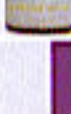
Visual Inspection - If the plants are growing well and have deep-green, healthy leaves, they are probably getting all necessary nutrients. The moment growth slows or the leaves begin to



Always use an accurate measuring container.



Pale green leaves signify this plant is low on nitrogen and needs to be fed with an all purpose fertilizer.

	18 hours of light			12 hours of light								
Week	1	2	3	4	5	6	7	8	9	10	...	
	Cuttings		Veg.	Flowering								
FloraGro*	0,25	0,25	0,5	1,5	1,5	0,5	0,5	0,5	0,5			
FloraMicro*	0,25	0,5	0,5	1	1	1	1	1	1			
FloraBloom*	0,25	0,25	0,5	0,5	0,5	1,5	1,5	1,5	1,5			
Bio Roots 	2 ml / 10 l			Roots activator								
Bio Protect* 			5		5		5	Immune system activator (Foliar spray, once a week)				
Bio Bloom 							2 ml / 10 l		Flowering activator			
Diamond Nectar* 				2		Strengthens the root system Improves the plant's general health						
Mineral Magic 				Increases the resistance to insects and disease (dosage : see label)								
Ripen 				10 last days for faster flowering								4 - 5

*Dosage in ml/l

Note : week 10 and more : depends on the plant's variety
Adjust your water's pH level regularly. You will find more details on your labels

General Hydroponics gives growers specific fertilizer and additive instructions for their products.

turn pale green, it is time to fertilize. Do not confuse yellow leaves caused by a lack of light with yellow leaves caused by a nutrient deficiency.

Taking an N-P-K soil test will reveal exactly how much of each major nutrient is available to the plant. The test kits mix a soil sample with a chemical. After the soil settles, a color reading is taken from the liquid and matched to a color chart. The appropriate percent of fertilizer is then added. This method is exact but more trouble than it is worth.

Experimenting on two or three test plants is the best way to gain experience and develop horticultural skills. Clones are perfect for this type of experiment. Give the test plants some fertilizer, and see if they green up and grow faster. You should notice a change within three to four days. If it is good for one, it should be good for all.

Now, it has been determined that the plants need fertilizer. How much? The answer is simple. Mix the fertilizer as per the instructions and water as normal, or dilute the fertilizer and apply

it more often. Many liquid fertilizers are very diluted already. Consider using more concentrated fertilizers whenever possible. Remember, small plants use much less fertilizer than large ones. Fertilize early in the day, so plants have all day to absorb and process the fertilizer.

It is difficult to explain how often to apply all fertilizers in a few sentences. We know that large plants use more nutrients than small plants. The more often the fertilizer is applied, the less concentrated it should be. Frequency of fertilization and dosage are two of the most widely disagreed upon subjects among growers. Indoor containerized marijuana can be pushed to incredible lengths. Some strains will absorb amazing amounts of fertilizer and grow well. Lots of growers add as much as one tablespoon per gallon of Peters™ (20-20-20) with each watering. This works best with growing mediums that drain readily and are easy to leach. Other growers use only rich, organic potting soil. No supplemental fertilizer is applied until a super bloom formula is needed for flowering.



Hesi SOIL

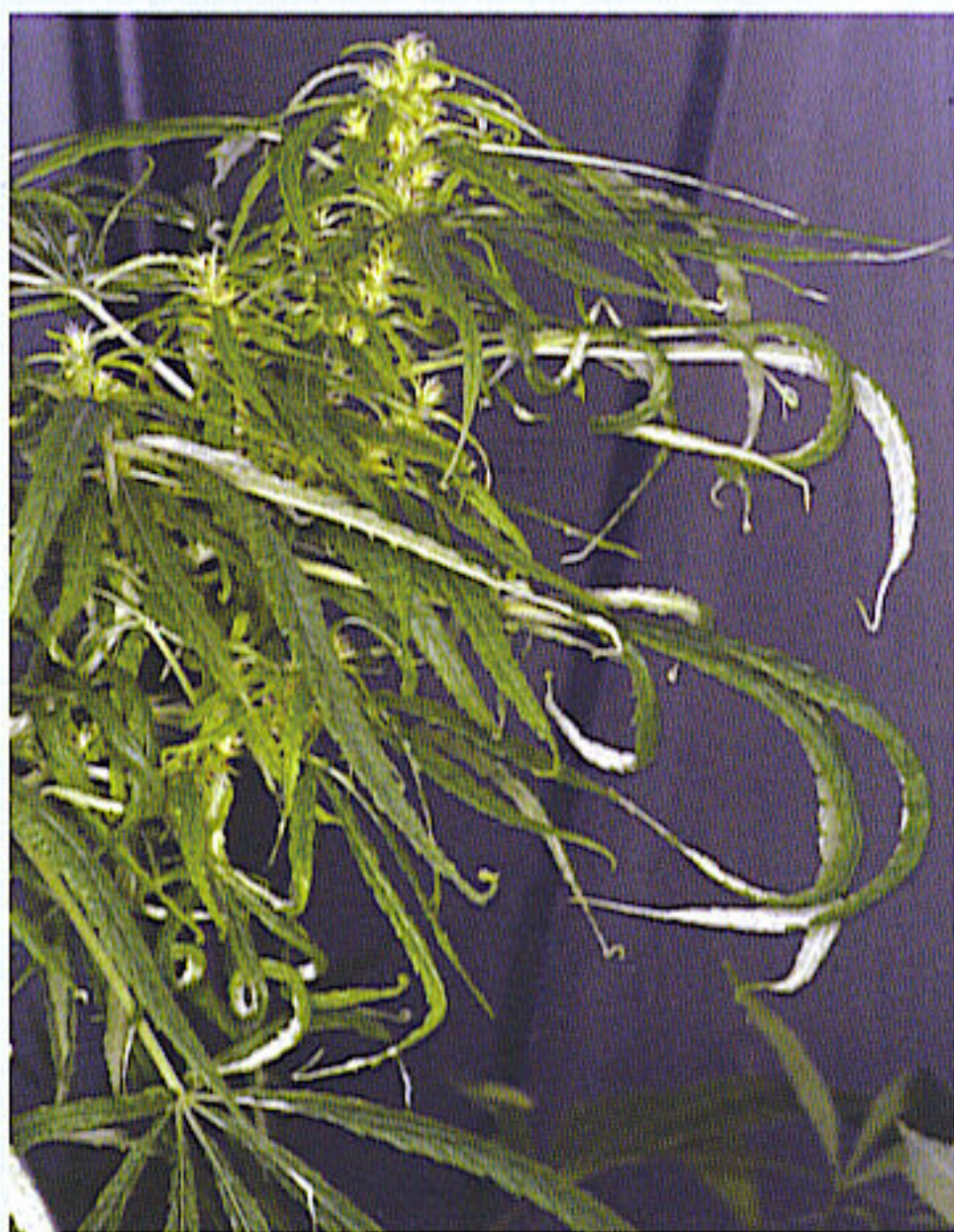
Grow schedule



week	-3	-2	-1	1	2	3	4	5	6	7	8
	CLONE	GROWTH									
Nutrients											
TNT Complex	25	50ml/10l									
BLOOM Complex							50 ml / 10 Ltr				
Phosphorus plus							25ml/10l				
BOOSTER											
ROOTS Complex											
Super Vit		1 drop	per 4,5 litres				water for		extra energy		
LIGHTING	18 HOURS			12 HOURS							

Flush with pure water

This Grow Schedule by Hesi details the exact feeding schedule for a super successful crop.



This 'Haze' plant is hypersensitive to fertilizer. Leaves curl when given slight overdose.

Fertilizing plants in the ground is much easier than fertilizing containerized plants. In the soil outdoors, roots can find many nutrients, and fertilization is not as critical. There are several ways to apply chemical fertilizer. You can top-dress a garden bed by applying the fertilizer evenly over the entire area. You can side-dress plants by



All leaves in this photo came from the same plant. All leaves show signs of overfertilization.

applying the fertilizer around the bases of the plants. You can foliar-feed plants by spraying a liquid fertilizer solution on the foliage. The method you choose will depend upon the kind of fertilizer, the needs of the plants, and the convenience of a chosen method.

When using synthetic fertilizers, it is extremely important to read the label carefully, and follow the directions. The initials "WSN" and "WIN" that you may see on the label stand for *water-soluble nitrogen* and *water-insoluble nitrogen*. WSN dissolves readily, and it is considered a fast-release nitrogen source. WIN does not dissolve easily. It is often an organic form of nitrogen and is considered a slow-release nitrogen source.

Use a siphon applicator—found at most nurseries—to mix soluble fertilizers with water. The applicator is simply attached to the faucet with the siphon submerged in the concentrated fertilizer solution with the hose attached to the other end. Often, applicators are set at a ratio of 1 to 15. This means that for every 1 unit of liquid concentrate fertilizer, 15 units of water will be mixed with it. Sufficient water flow is necessary for the suction to work properly. Misting nozzles restrict this flow. When the water is turned on, the fertilizer is siphoned into the system and flows out the hose. The fertilizer is generally applied with each watering, since a small percentage of fertilizer is metered in.

A garbage can with a garden-hose fitting attached at the bottom that is set 3-4 feet (90-120 cm) off the floor will act as a gravity-flow source for the fertilizer solution. The container is filled with water and fertilizer.

When it comes to fertilization, experience with specific varieties and growing systems will tell growers more than anything else. There are hundreds of N-P-K mixes, and they all work! When choosing a fertilizer, make sure to read the entire label, and know what the fertilizer claims it can do. Do not be afraid to ask the retail clerk questions or to contact the manufacturer with questions.

Once you have an idea of how often to fertilize, put the garden on a regular feeding schedule. A schedule usually works very well, but it must be combined with a vigilant, caring eye that looks for over-fertilization and signs of nutrient deficiency.



Spray foliage from underneath so the spray is able to penetrate the stomata located on the leaf's underside.



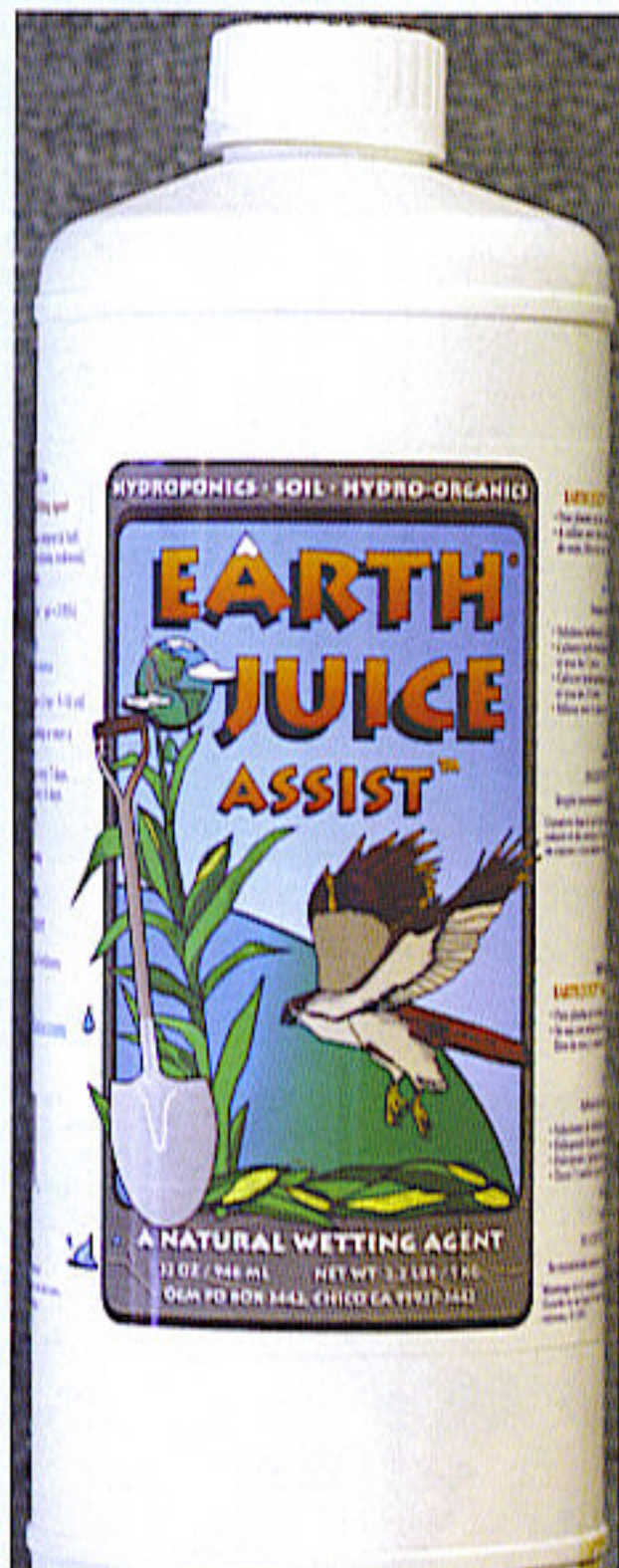
Leaves and stalks have waxy, cystolith hairs that act like feathers on a duck and shed water.

Stomata close when there is:

Too much CO₂
Low humidity
A dry root system

Stomata open when there is:

High light
Low CO₂
High Humidity



Earth Juice Wetting Agent

Leach soil with 1-2 gallons (4-8 liters) of mild nutrient solution per gallon of soil every month. This is the best form of preventive maintenance against toxic salt buildup in the soil.

Foliar Feeding

Foliar feeding means to spray the nutrients or bio-stimulants onto the foliage to augment available nutrients, vitamins, hormones, etc. Timing is key to achieving the

best coverage and absorption.

The waxy (cuticle) surface coating (cystolith hairs and resin) on cannabis foliage makes them very poor water absorbers. This barrier wards off pest and disease attacks, but it also slows the penetration of sprays.

Young leaves are more permeable than older leaves. Nutrients and additives penetrate immature leaves faster than tougher, older leaves, and they are easier to damage with strong sprays.

Foliar feed the cannabis plants only when specific deficiency symptoms manifest. Foliar feeding is a quick fix only and is easy to overdo. High levels of nutrients in the foliage stop the roots from taking in more; this is confusing for the plant. Foliar sprays can accumulate and build up in the foliage. Never spray more than once every 10 days, and keep the spray concentration to less than 500 ppm or with an EC of less than 1.0.

Spreader-Stickers

Smart growers use a surfactant, surface-active substance (adjuvant), which enhances the effectiveness of foliar fertilization.

Spreaders (wetting agents) reduce the surface tension of sprays and keep them from beading up and rolling off the foliage. Big, bulbous drops on the leaves mean you need to use a spreader. Flat drops that slide off the foliage mean there is too much spreader. There are nonionic, antionic, and cationic spreaders. The nonionic spreaders that do not ionize in water are the most common, and they do not react with most pesticides. Antionic and cationic spreaders are not used often.

Stickers help the spray adhere to the leaf after spraying, so it does not wash off when it rains or when dew forms. Stickers not only increase adhesion, they slow evaporation, and impart a waterproof coating. Some stickers are spreaders, too. Spreader-stickers allow the stomata on the leaves to be penetrated.

Extender (stabilizing agents) protects applied sprays against the UV radiation and heat that degrade the sprays.

Liquid and powder soaps and detergents act as surfactants, too. But, they are not nearly as effective as horticultural surfactants. Biodegradable surfactants disappear the fastest. Silicone surfactants are also mild insecticides that work to impair pest functions.

Foliar spray concentration is cumulative. Nutrients delivered via the foliage can cause a buildup of salts in and around the leaves. This is similar to the way the salts accumulate in the soil.

Overfertilizing can become one of the biggest problems for indoor growers. Too much fertilizer causes a buildup of the nutrients (salts) to toxic levels, and it changes the soil chemistry. When overfertilized, growth is rapid and lush until the toxic levels are reached. At this point, things become complicated.

Chance of overfertilization is greater in a small amount of soil that can hold only a small amount of nutrients. A large pot or planter can safely hold much more soil and nutrients, but it will take longer to flush if overdone. It is very easy to add too much fertilizer to a small container. Large containers have good nutrient-

holding ability.

To treat severely overfertilized plants, leach the soil with two gallons (8 L) of diluted nutrient solution per gallon (4 L) of soil to wash out all excess nutrients. The plant should start new growth and look better in one week. If the problem is severe and the leaves are curled, the soil may need to be leached several times. After the plant appears to have leveled off to normal growth, apply the diluted fertilizer solution.

Additives

Numerous additives or growth supplements have hit the market over the last few years. Generally, additives contain a cocktail of some

of the elements listed below. Most of the additives came from the greenhouse industry or were developed for organic growers. Many of these additives do what they say they will do and work quickly; however, when growing a short eight- to ten-week crop, some of these additives do not have time to work properly if added near the end of the flowering cycle.

The following list will give you an idea of what specific additives are and how they are used.

ABSCISIC ACID (ABA)

Absciscic acid is a naturally occurring hormone that assists plants in adapting to environmental stresses like drought or cold temperatures.

How to get the most out of your spray

1) Spray the bottom of the leaves. Spray with a fine mist, and do not create droplets on the leaves. Fine mist is electrically attracted by the foliage. Even young marijuana plants have waxy hairs that impair liquid penetration.

2) Do not spray plants that are hot or when the atmosphere is too dry. Spray in low light, either before the lights go off or just as they are coming on. If spraying in hot conditions, first spray everything with plain water until the temperatures of the room and foliage drop, before applying the real spray. Spraying when the plant foliage is hot causes the spray to crystallize on the surface, and it stops the penetration. Spraying with water 10 minutes afterward often increases the penetration. Mobile nutrients move freely within a plant. Immobile nutrients move slowly, but once deposited, they stay.

3) Apply mobile nutrients sparingly. Immobile nutrients—sulfur, boron, copper, iron, manganese, molybdenum, sulfur, and zinc—often require two or three applications. Calcium and boron are poor candidates for foliar feeding because they translocate poorly. But urea nitrogen applied as a spray in high humidity penetrates almost instantly into leaves. Be careful when spraying urea-based fertilizers, and keep them diluted. Urea also carries other nutrients into the plant and

works well for a base to the mix. Foliar feeding should turn the plant around in less than a week. A second spray could be necessary at week's end to ensure the cure sticks.

4) Boron, calcium, and iron move slowly during flowering. A supplemental foliar dose often speeds the growth when it slows. A foliar spray of potassium can also help flowering, especially if the temperatures dip below 50°F (10°C) or above 80°F (25°C).

5) Always spray new growth. The thin, waxy layer and a few trichomes allow for good penetration.

6) Measure the pH of the spray, and keep it between 7 and 8.5. Potassium phosphate (K_2HPO_4) becomes phytotoxic below pH 4 and above 8.5. Stomata are signaled to close within these pH ranges.

7) Use a surfactant with all sprays, and apply these as per the instructions on the label.

8) Add the proper amount of surfactant so droplets do not form on the leaves. Once formed, the droplets roll off the foliage, rendering it ineffective.

9) Stop the application before the droplets form on the leaves. Make a test spray on a mirror to ensure the spray is even and does not form droplets that roll off the mirror.

10) Spray with as fine a mist as possible to minimize the size of the drop.



Use a spreader/sticker to keep spray droplets from bouncing off foliage.

During winter, ABA converts leaves into stiff bud scales which cover the meristem, protecting it from cold damage or dehydration. In case of an early spring, ABA will also prolong dormancy, preventing premature sprouts which could be damaged by frost.

Used in the garden, ABA may help plants resist drought and unseasonable conditions and improve productivity, strength, and performance.

ASCORBIC ACID (Vitamin C)

Vitamin C is thought to build tighter, heavier buds and act as an antioxidant. It is often combined with fructose, molasses, or sugar and added to the nutrient solution during the last two weeks before harvest. However, some botanists believe that although vitamin C is very important in fighting the free radical byproducts of photosynthesis, plants make their own vitamin C and are unlikely to recognize any benefit from its addition to the nutrient mix.

ASPIRIN

Salicylic acid is a naturally occurring plant hormone associated with the Willow. It is effective in preventing pathogens by speeding up the natural "systemic acquired resistance (SAR)" thereby reducing the need for pesticides. Salicylic acid (SA) will block abscisic acid (ABA) allowing the plant to return to normal after a period of stress—something to consider if ABA is

being used to strengthen plants.

Aspirin can be used as a spray, a soak, or added to compost and rooting compounds. A 1:10,000 solution used as a spray will stimulate the SAR response, and the effects will last weeks to months. "Willow water" also makes a popular rooting bath.

AUXINS

Auxins represent a group of plant hormones that regulate growth and phototropism. They are associated

with elongation of plant cells causing the branches to grow vertically while inhibiting lateral buds. "Pinching off" branch tips will reduce the auxin level and encourage bushy lateral growth as well as inducing new root formation.

Synthetic auxins are more stable and last longer than the natural solutions. They can be used as an herbicide against broadleaf weeds like dandelions, but are most often used to encourage root growth and promote flowering.

BACTERIA

Bacteria such as mycorrhizal fungi and rhizobacteria are extremely beneficial in organic gardening. The presence of these organisms in the growing medium produces stronger, healthier plants that require less chemical intervention.

Actino-Iron is a commercial soil additive that contains the *streptomyces lydicus* microbe. Applied to the soil, the bacterium grows around the root system, protecting it from harmful pathogens while producing anti-fungals. Actino-Iron also contains fulvic acid and iron which feed the plant. For perennials, the effects last one growing season. For annuals, the life of the plant.

B-9 FOLIC ACID

There is little literature on the effects of B-9 on plants. It appears to serve in energy transfer within the plant and inhibits the enzyme that makes gibberellic acid resulting in a bushier dwarf-type plant without pruning.

B-9 can be applied as a spray or as a soil drench.

CELLULASE

Cellulase is a group of enzymes that act in the root zone to break down organic material which may rot and cause disease. Dead materials are converted into glucose and returned to the substrate to be absorbed by the plant.

It can be used in water gardens to clean up organic sludge.

COLCHICINE

Colchicine, an alkaloid, is prepared from the dried corns and seeds of *Colchicum autumnale*, the autumn crocus that also produces saffron. The pale, yellow powder is water soluble.

Colchicine is a *very dangerous, poisonous* compound that can be used to induce polyploid mutations in cannabis. Clandestine breeders started polyploid strains with colchicines, but none of the strains showed any outstanding characteristics, and cannabinoid levels were unaffected.

Rather than explain how to use colchicine, I will advise not to use it. It is very toxic and produces no change in potency. I do not know any seed breeders that use it today.

CYTOKININS

Cytokinins are plant hormones derivative of the purine adenine, the most common cytokinin being Zeatin. They are synthesized in the roots promoting cell division, chloroplast development, leaf development, and leaf senescence. As an additive, cytokinins are most often derived from the Seaweed *Ascophyllum nodosum*.

Added to the soil or sprayed on the plants, cytokinins help the plant make more efficient use of existing nutrients and water even in drought conditions. The result is a healthier plant and increased crop. Care must be given to application of cytokinins along with other plant hormones. Many commercial formulas contain a hormone cocktail which includes hormones like auxins and cytokinins that work against one another.

ENZYMES

Enzymes are biological protein catalysts that were first crystallized and isolated in 1926. Enzymes accelerate the rates of reactions but do not change themselves as a result of this action.



Without a spreader-sticker, the surfactant sprays often bead up and roll off the foliage which makes them ineffective.

Enzymes are added to fertilizers and growth additives to accelerate biological activity and speed nutrient uptake by roots.

Most enzymatic reactions happen within a temperature range of 85-105°F (30-40°C) and each enzyme has an optimal range of pH for activity. Most enzymes react with only a small group of chemical compounds that are closely related.

More than 1500 different enzymes have been identified. Enzymes are grouped into six main classes and many subclasses.

ETHYLENE GAS

Ethylene gas is a growth regulator hormone that activates the aging and ripening of flowers as well as preventing the development of buds and retarding plant growth. It is most often used by vegetable growers who force ripening of produce heading to market. In gardening, it may be used to trigger flowering in plants.

FLOWER SAVER PLUS

Flower Saver Plus is a commercial product that contains the Mycorrhizae fungus which enters into a symbiotic relationship with the plant by attaching itself to the root system. Mycorrhizal threads enter into root tissue then grow out into

the substrate reaching more water and nutrients than the plant could find on its own. In return, the Mycorrhizae receive a protected environment and the sugars they need to thrive.

Use of Mycorrhizae improves root depth, speeds maturation, and helps create resistance to drought and disease. Larger more robust root systems also improve the soil structure promoting better air and water movement.

Flower Saver Plus should be used at planting time either as a root bath or worked into the top two to four inches of soil. Look for a product that has at least 50 to 100 spores per square foot.

Seek medical attention if ingested. Avoid breathing the dust or spray, and keep out of reach of children.

FULVIC ACID

Fulvic acid is a naturally occurring organic substance resulting from the microbial action on decomposing plants. Absorbed into a plant, fulvic acid will remain in the tissues and serve as a powerful antioxidant as well as providing nutrients and acting as a bio-stimulant. Fulvic acid is an excellent source of nutrition for Mycorrhizae.

Growers can create fulvic acid by composting or purchase the product from a retailer. It is available in forms suitable for hydroponics or soil mediums.

GIBBERELLINS

Gibberellic Acid (GA) is a natural plant growth hormone which acts with auxins to break dormancy, stimulate seed germination, and grow long stems.

Gibberellic Acid can be purchased as a commercial product like Mega-Grow and is used to extend the grow season and force larger blooms. For best effect, use GA in complement with fertilizer and mixed into the water supply. Results can be seen in as little as a few weeks.

According to the Material Safety Data Sheet (MSDS), GA is very hazardous to humans, and I do not advise using it; however, the retail advertisements claim the product is safe.

HUMIC ACID

Humic acids are carbons formed by the decomposition of organic substances, primarily that of vegetation. Applied to substrate, it encourages the creation of strong tissue growth and helps in nutrient transport. Plants grow

thicker foliage and are more resistant to drought and disease.

Poor soils can be improved by humic acid which enhances the water-holding capability and aeration in sandy soils and frees up nutrients bound in clay. It can be used as a root dip or sprayed directly onto the soil.

Humic acids are extracted from humic substances found in soil. Colors range from yellow (fulvic acid) to brown (humic acid) and black (humin).

Fulvic acid is the fraction of humic substances that is water soluble under all pH conditions. Fulvic acid stays in solution after humic acid dissipates due to acidification.

Humin is the fraction of the soil organic matter that is not dissolved when the soil is treated with dilute alkali.

HYDROGEN PEROXIDE

Hydrogen peroxide (H_2O_2) is similar to water but carries an extra, unstable, oxygen molecule which can break down into a reactive atom and either attach itself to another oxygen atom or attack an organic molecule.

Used in horticulture, hydrogen peroxide provides a host of benefits by cleansing water of harmful substances such as spores, dead organic material, and disease-causing organisms while preventing new infections from occurring. It removes the methane and organic sulfates often found in well water as well as removing chlorine from tap water.

Hydrogen peroxide is especially useful in hydroponics, where overwatering can be a problem. It prevents oxygen depletion in the water around the roots, leading to better root growth. A solution of hydrogen peroxide can be used to sterilize seeds resulting in better germination rates.

Hydrogen peroxide is dangerous at high concentrations (35%) and will damage skin, clothing, and most anything it contacts. Lower concentrations like those found at the drug store (3%) will still need to be diluted before use, though they are not as toxic to the gardener.

INDOLE 3 BUTYRIC ACID (IBA)

Indole 3 butyric acid is one of the auxin growth hormones. It is most often used as an effective rooting hormone. Application of IBA helps gen-

erate roots, build a larger root mass, and improve plant growth and yield.

Many commercial formulas are available in the form of water-soluble salts. Cuttings can be dipped or immersed before planting. Roots can be dipped or sprayed or the soil drenched during transplanting. Once established, plants should be treated at three- to five-week intervals during the growing season. After harvest, IBA can be used to encourage regeneration of flowers.

IBA is hazardous to humans and animals. It can cause moderate eye injury and is harmful if inhaled or absorbed through the skin.

ISOPENTYL ADENINE (IPA)

Isopentyl adenine is a naturally occurring cytokinin which is synthetically manufactured as benzylaminopurine (BAP) for use in commercial bio-stimulants such as Rush Foliar XCell Veg and Xcell Bloom.

Xcell Veg acts in the growth stage of the plant by improving the transport of nutrients. Glycine betaine in the solution provides a barrier to environmental stress. The product is used as part of an established feeding program. It can be sprayed on, just before turning off the lights, or used as a soak in the growing medium.

Xcell Bloom also has anti-stress properties and improves nutrient transport. It stimulates flowering, reduces plant growth time, and increases cell division and lateral root growth. Flowers are larger, heavier, and have enhanced color.

Both products can be used in hydroponic or soil mediums.

RHIZOBIUM

Rhizobium is the name given to a group of bacteria which infect the roots of legumes and create nodules that act in symbiosis with the plant. Rhizobia are host-specific and will not work with all crops. With the proper host, however, rhizobia improve nitrogen fixation while simultaneously providing an additional source of nitrogen.

Rhizobium is most effective when added to irrigation, but it can be added to a drip or directly to the soil. Benefits will depend on proper crop/rhizobium match. Re-inoculation is recommended every three to five years.

SPRAY-N-GROW

Spray-N-Grow is a brand name vitamin and nutrient solution that includes barium and zinc. It is sprayed on plants to provide micronutrients through the foliage, a technique said to be more effective than root nutrition. Plants will grow faster, bloom earlier and more prolifically, have larger roots, and have a higher vitamin, mineral, and sugar content.

Because it is absorbed through the leaves, Spray-N-Grow works quickly, in as little as seven to thirty days. Tender plants will realize benefits faster than woody plants. Spray-N-Grow can be used in any type of growing medium as a complement to the established feeding regimen. It is non-chemical and safe for people and pets.

SUGAR

Molasses, honey, and other sugars are said to increase soil microbials, enhance regrowth, and make the plant's use of nitrogen more effective. Molasses will raise the energy level of the plant and acts as a mild natural fungicide. Molasses is the "secret ingredient" in many organic fertilizers.

TRICHODERMA (002/003)

Trichoderma are fungi that colonize in the root zone, crowding out negative fungi and microorganisms while stimulating root development and resistance to environmental stress. The result is a more vibrant, stronger plant.

Canna was the first company in the indoor grow industry to sell a commercial product as a growth-promoter which contains Trichoderma fungi. Colorado State University studies indicate that Promot Plus, a product containing trichoderma, is effective in suppressing pathogenic fungi that cause rot in the seeds, roots, and stems.

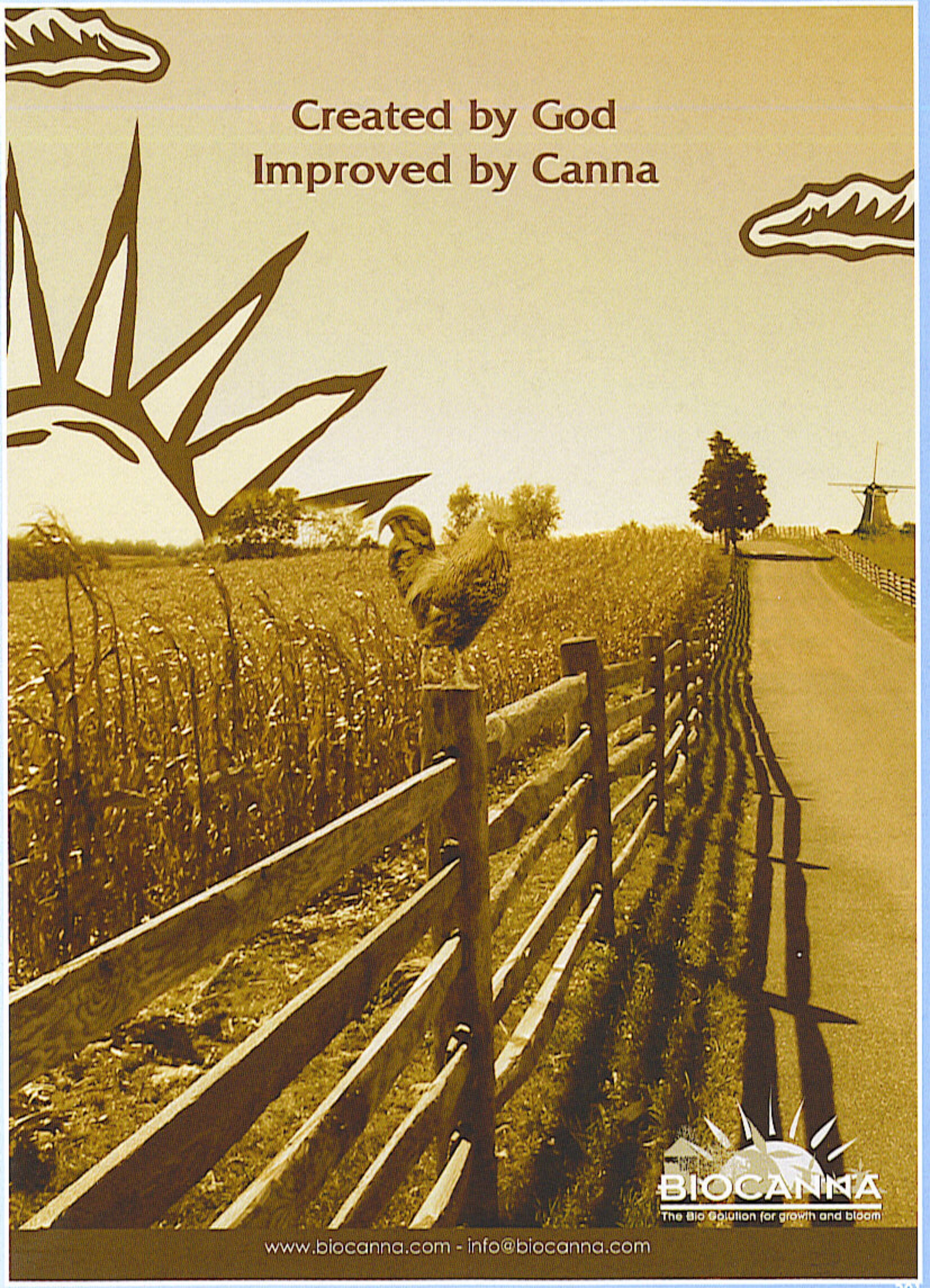
The product can be applied to seeds, used during transplanting, mixed with liquid fertilizer or via drip irrigation and/or watered in. Canna's Trichoderma contains living organisms that will reproduce after application, so a small amount will do a lot. It is nontoxic and environmentally safe.

ZEATIN

Zeatin is one of the cytokinin growth hormones. Upon germination, zeatin moves from the endosperm to the root tip where it stimulates mitosis.







Created by God
Improved by Canna



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The Bio Solution for growth and bloom

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Know **B4U** Grow!

SURGEON GENERAL'S WARNING:

Using this grow game gives you insight in how to grow your own. It can lead to very serious time spending, lack of nutrients, poor social life and repetitive strain injury!



CANNA
The solution for growth and bloom

Chapter TWELVE

HYDROPONIC GARDENING



This Swiss hydroponic setup is simple, efficient, and economical.

Introduction

Hydroponics is the science of growing plants without soil, most often in a soilless mix. In fact, many growers are already cultivating hydroponically. Cultivating clones in rockwool, peat moss, and coconut fiber is growing hydroponically. Growing mature plants in soilless Sunshine Mix or Terra-Lite, even when watered by hand, is hydroponic gardening. With hydroponics, nutrient uptake and grow medium oxygen content can be controlled easily. Manage these two factors, along with a few other requirements, to grow a bumper crop of buds with every harvest.

The inert soilless hydroponic medium contains essentially no nutrients. All the nutrients are supplied via the nutrient solution—fertilizer diluted in water. This solution passes over or floods around roots at regular intervals, later draining off. The extra oxygen trapped in the soilless medium and around the roots speeds nutrient uptake by tiny root hairs. Cannabis grows fast hydroponically, because it is able to take in food as fast as it can be used. In soil, as in hydroponics, the roots absorb nutrients and water. Even the best soil rarely has as much oxygen in it as a soilless hydroponic medium.

Contrary to popular belief, hydroponic gardens often require more care than soil gardens. If growing hydroponically, expect to spend more time in the garden. Extra maintenance is necessary because plants grow faster, there are more things to check, and more can go wrong. In fact, some growers do not like hydroponic gardening, because it requires too much additional care.

Hydroponic gardening is productive, but exacting—not as forgiving as soil gardening. Soil works as a buffer for nutrients and holds them longer than inert hydroponic growing mediums. In fact, advanced aeroponic systems do not use a soilless mix; they use nothing at all!

In hydroponics, the nutrient solution can be controlled, so plants grow less leafy foliage and more dense flower buds. The stepped-up nutrient control makes plants flower faster and be ready for harvest a few days earlier than soil-grown cannabis.

Small flowering plants grow well in small hydroponic containers and horizontal tubes. Mother plants grow longer and are best suited to a large bucket system, which allows room for root development. The mother plants' root system is easily contained in the bucket, and she is able to produce



Good looking buds are grown hydroponically in expanded clay pellets, an inert soilless medium. Plants can take in all the nutrients they need.

thousands of clones during her lifetime. Mother plants must have a huge root system to take in lots of nutrients to keep up with the heavy growth and clone production schedule.

Most grow rooms have two limiting factors: the number of plants in the garden and the electrical consumption expressed in watts. For example, if growing 12 large plants in a five-gallon (19 L) bucket hydroponic system, you will need about ten clones and one mother plant. The flowering room could be illuminated with two 600-watt HP sodium lamps. A 40-watt fluorescent fixture could be used to root clones, and a 175-watt metal halide will keep the mother and vegetative plants growing. This is a total of 1415 watts that cost about \$35 to \$60 monthly. That's a bargain, considering the garden will yield at least a pound (450 gm) of beautiful hydroponic buds every month!

If flowering is induced when clones are six to eight inches (15-20 cm) tall, they will be two to three feet (60-80 cm) tall when they finish flowering. You can pack short plants tightly together in a "sea of green" (SOG) or a "screen of green" (SCROG) to maximize yield. It is easy to grow 60,

four-inch (10 cm) rockwool cubes on a flood and drain table or in three-gallon (11 L) grow bags full of soilless medium. To get the maximum yield, a plant or two is harvested every day or two. When a ripe plant is harvested, two small clones take its place. The weaker clone is culled out after two weeks.

Different Systems

Hydroponic systems are distinguished by the way the nutrient solution is applied. The first distinction is whether the nutrient solution is applied in an "active" or "passive" manner.

Passive systems rely on capillary action to transfer the nutrient solution from the reservoir to the growing medium. Nutrient solution is passively absorbed by a wick or growing medium and transported to the roots. Absorbent growing mediums such as vermiculite, sawdust, peat moss, etc., are ideal for passive systems. The growing medium can stay very wet in passive systems, and substrate selection is important. Soggy substrates hold less air and deprive roots of rapid nutrient uptake. Although passive gardens are not considered "high



This flood hydroponic garden, fertilized with Bio-Green, uses a soilless mix heavy in coco peat. All nutrients are supplied by the nutrient solution.



Classic wick gardens use cloth wicks that absorb nutrient solution and transport it to the growing medium.



This passive wick system uses a soilless mix heavy in coco peat to wick up the nutrient solution. Such low-tech gardens are very productive.

performance," the Dutch have managed to perfect them and achieve amazing results. Wick systems have no moving parts. Seldom does anything break or malfunction. Low initial cost and low maintenance enhance wick systems' popularity.

Dutch growers line the floor of a room with heavy plastic or pond liner. They fill three-gallon (3 L) pots with an absorbent soilless mix that holds plenty of air. They flood the garden with two to three inches (6-9 cm) of nutrient solution. Roots absorb the nutrient solution in two to five days. No nutrient solution is drained off; it is all absorbed by plants!

One Spanish grower uses passive irrigation to water his garden. He drives a delivery truck and is away from home five days a week. He keeps his indoor garden under a 400-watt HPS lamp. The plants are in a rich potting soil, and the pots are in a large tray with four-inch (12 cm) sides. Every Monday morning he fills the tray with mild nutrient solution. When he returns on Friday, the plants are strong and happy!

Active hydroponic systems "actively" move the nutrient solution. Examples of active systems are: flood and drain, and top feed. Cannabis is a fast-growing plant and very well suited to active hydroponic systems.

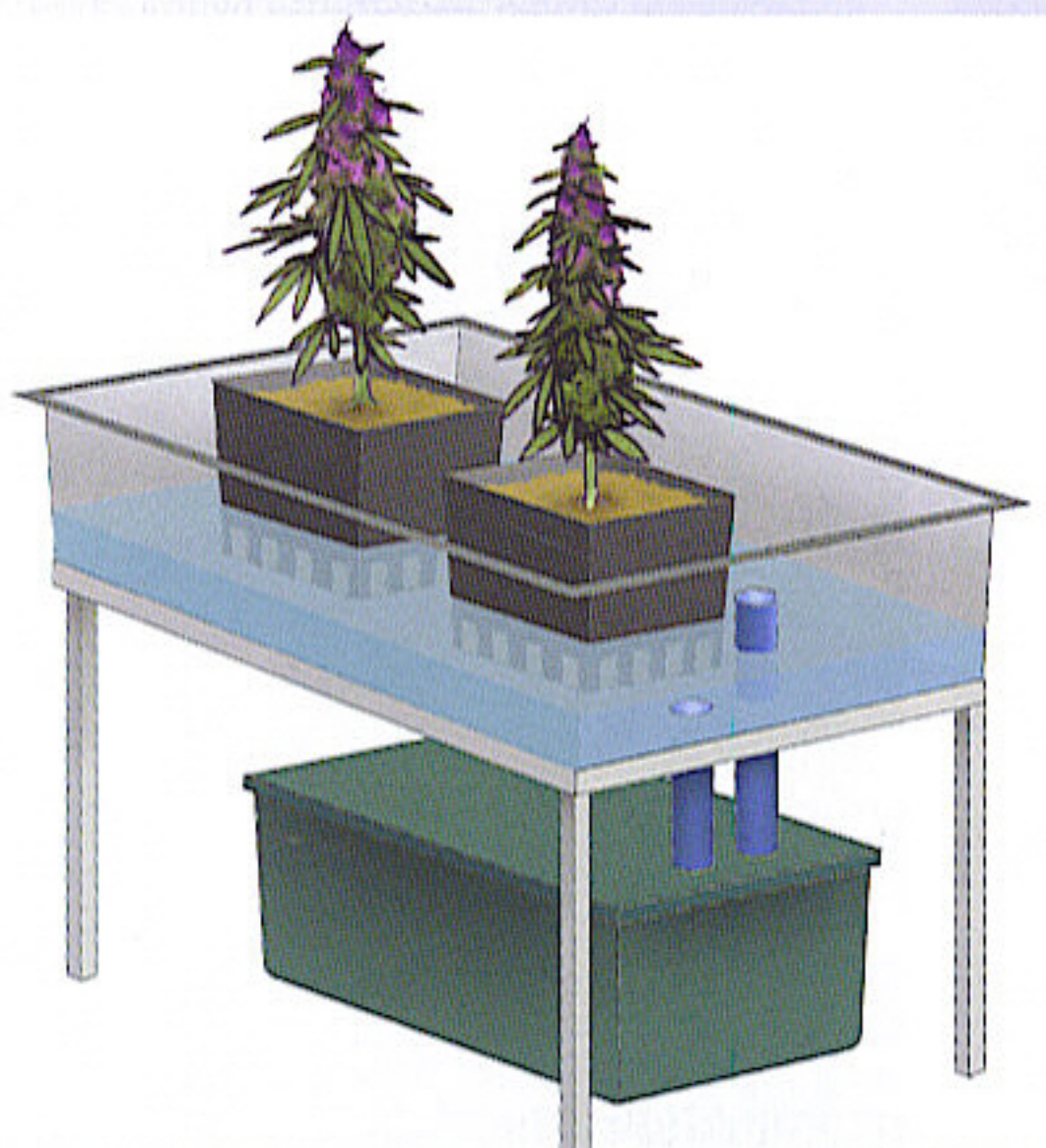
Active hydroponic gardens are considered a "recovery" system if the nutrient solution is recovered and reused after irrigation. A "non-recovery" system applies the nutrient solution once, then it runs to waste. The solution is not reused. Non-recovery systems have few complications but are not practical for most cannabis hydroponic gardens. The commercial growers "run-to-waste" systems are avoided, because they pollute ground water with high levels of nitrates, phosphates, and other elements. Indoor growers seldom use non-recovery systems, because they require disposing of so much nutrient solution into the local sewer system.

Active recovery hydroponic systems such as the flood and drain (ebb and flow), top feed, and nutrient film technique (NFT) are the most popular and productive available today. All three systems cycle reused nutrient solution into contact with roots. Recovering and reusing the nutrient solution

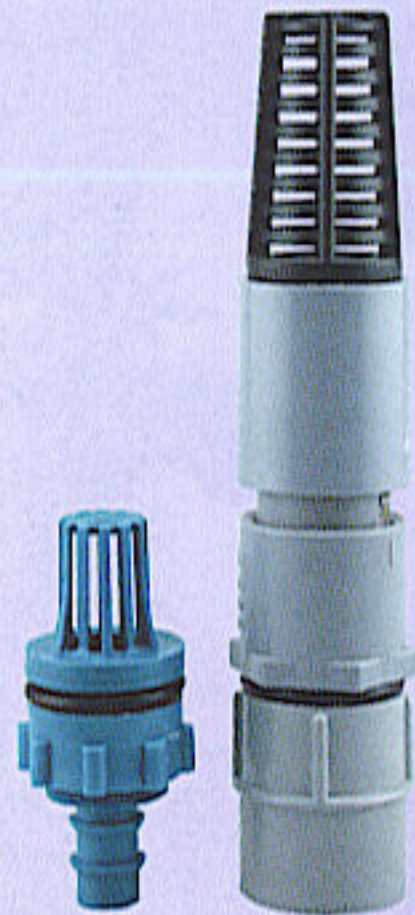
makes management more complex, but with the proper nutrient solution, schedule, and a little experience, it is easy to manage. Active recovery systems use growing mediums that drain rapidly and hold plenty of air, including: expanded clay, pea gravel, pumice rock, crushed brick, rockwool, and coconut coir.

Ebb and Flow Gardens

Ebb and flow (flood and drain) hydroponic systems are popular because they have proven track records as low maintenance, easy-to-use gardens. Ebb and flow systems are versatile, simple by design, and very efficient. Individual plants in pots or rockwool cubes are set on a special table. The table is a growing bed that can hold one to four inches (3-10 cm) of nutrient solution. Nutrient solution is pumped into the table or growing bed. The rockwool blocks or containers are flooded from the bottom, which pushes the oxygen-poor air out. Once the nutrient solution reaches a set level, an overflow pipe drains the excess to the reservoir. When the pump is turned off and the growing medium drains, it draws new oxygen-rich air into contact with the roots. A maze of drainage gullies in the bottom of the table directs runoff solution back to the catchment tank or reservoir. This cycle is repeated several times a day. Ebb and flow systems are ideal for growing many short plants in a Sea of Green garden.



Nutrient solution floods the growing bed and drains back into a reservoir in an ebb and flow garden.



Nutrient solution is pumped up into the bed via the short flood fitting on the left. The overflow fitting on the right guarantees the nutrient solution will not spill over the top of the table.



Self-leveling legs, similar to those of a washing machine, support this ebb and flow garden bed and ensure all plants receive a level dose of nutrient solution and that it all drains back into the reservoir below.



Nutrient solution can be applied from above and the table serves as a drain.

Flood the table to half to three-quarters the height of the container to ensure even nutrient solution distribution. Avoid lightweight mediums such as perlite that may cause containers to float and fall over.

A large volume of water is necessary to fill the entire table. Make sure the reservoir has enough solution to flood the reservoir and still retain a minimum of 25 percent extra to allow for daily evaporation. Replenish reservoir daily if necessary. Do not let nutrient solution stand in the table for more than a half hour. Submerged roots drown in the depleted oxygen environment.

Flood the table when the medium is about half-full of moisture. Remember, rockwool holds a lot of moisture. Irrigation regimens will need to change substantially when temperatures cool and light is lacking.

Ebb and flow tables or growing beds are designed to let excess water flow freely away from the growing medium and roots. When flooded with an inch (3 cm) or more of nutrient solution, the growing medium wicks up the solution into the freshly aerated medium.

Air Table

Air tables are simple, easy-to-use hydroponic gardens. Seasoned growers and novices love their simplicity and low maintenance. The unique oper-



The grow room is lined with white Visqueen. The grower takes off his shoes to avoid damaging the plastic and to keep the grow show clean.



Growing is easy and efficient in this beautiful Visqueen-lined room.

ating principle is simple, effective, and nearly fail-safe. The nutrient solution is forced up to the growing bed with air pressure generated by an external air pump. The pump can run on ordinary household electrical current or a solar-powered 12-volt system. Once flooded, the nutrient solution stays in the growing bed for a few minutes before it drains back to the reservoir. Constant air pressure during flooding also aerates the growing medium. The sealed, airtight reservoir limits evaporation, which in turn prevents algae growth and keeps the nutrient fresh. The external pump reduces the overall cost of the system and helps prevent electrical accidents. You can use rockwool, coco coir, peat, or a composite growing medium with excellent results. Check out the Terraponic air table at www.fearlessgardener.com.

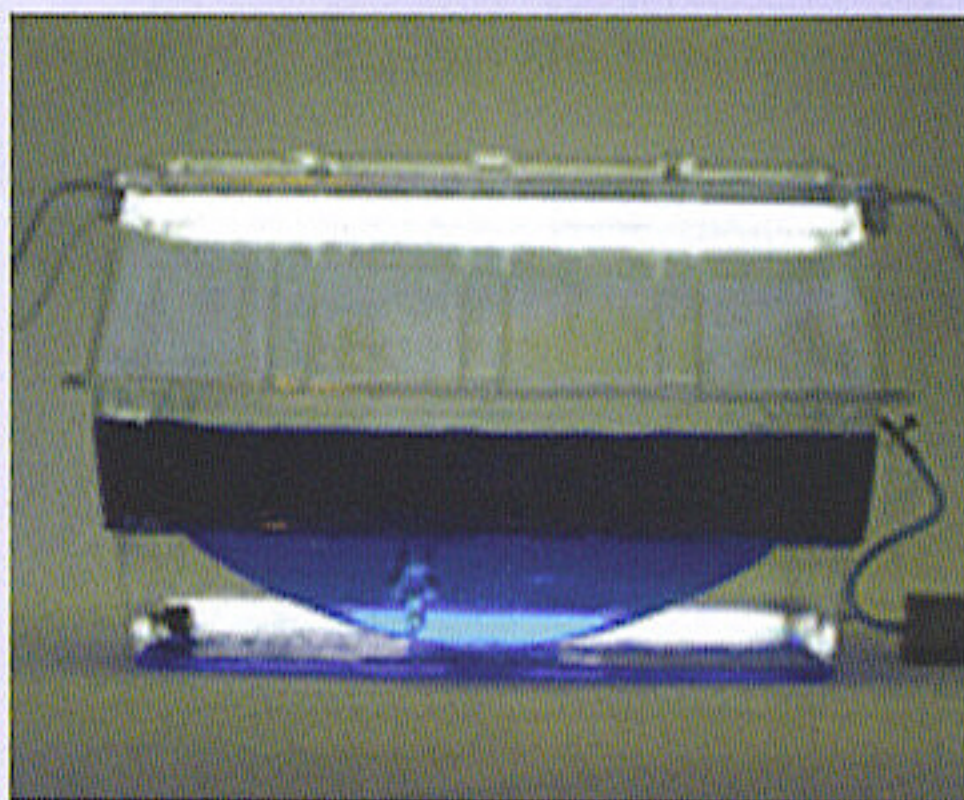
Deep Water Culture (DWC)

Growing in deep water culture (DWC) is simple, easy, and productive.

If growing outdoors in a DWC garden, a simple overflow drainage hole can be cut in the side of the reservoir to prevent rainwater from causing it to overflow.

Seedlings and clones are held in net pots full of expanded clay pellets, rockwool or other growing medium. The net pots are nestled in holes in a lid that covers the reservoir. The roots of seedlings and cuttings dangle down into the nutrient solution. A submersible pump lifts nutrient solution to the top of a discharge tube where it splashes into the access lid. Nutrient solution cascades down, wetting roots and splashing into the self-contained reservoir below, which in turn increases dissolved oxygen in the solution. Roots easily absorb nutrients and water from the solution in the oxygenated environment. Many gardens also keep an air stone bubbling new air into the reservoir to supply more oxygen.

These gardens are simple by design and require no timer, because the pumps are on 24 hours a day. This low-maintenance garden is perfect for casual gardeners as well as hydroponic enthusiasts.



The simple air table design makes them low maintenance. Air is pumped into a reservoir filled with nutrient solution. The air pressure forces the solution up into the growing bed.



This ingenious DWC garden uses an air pump to aerate and agitate the nutrient solution.



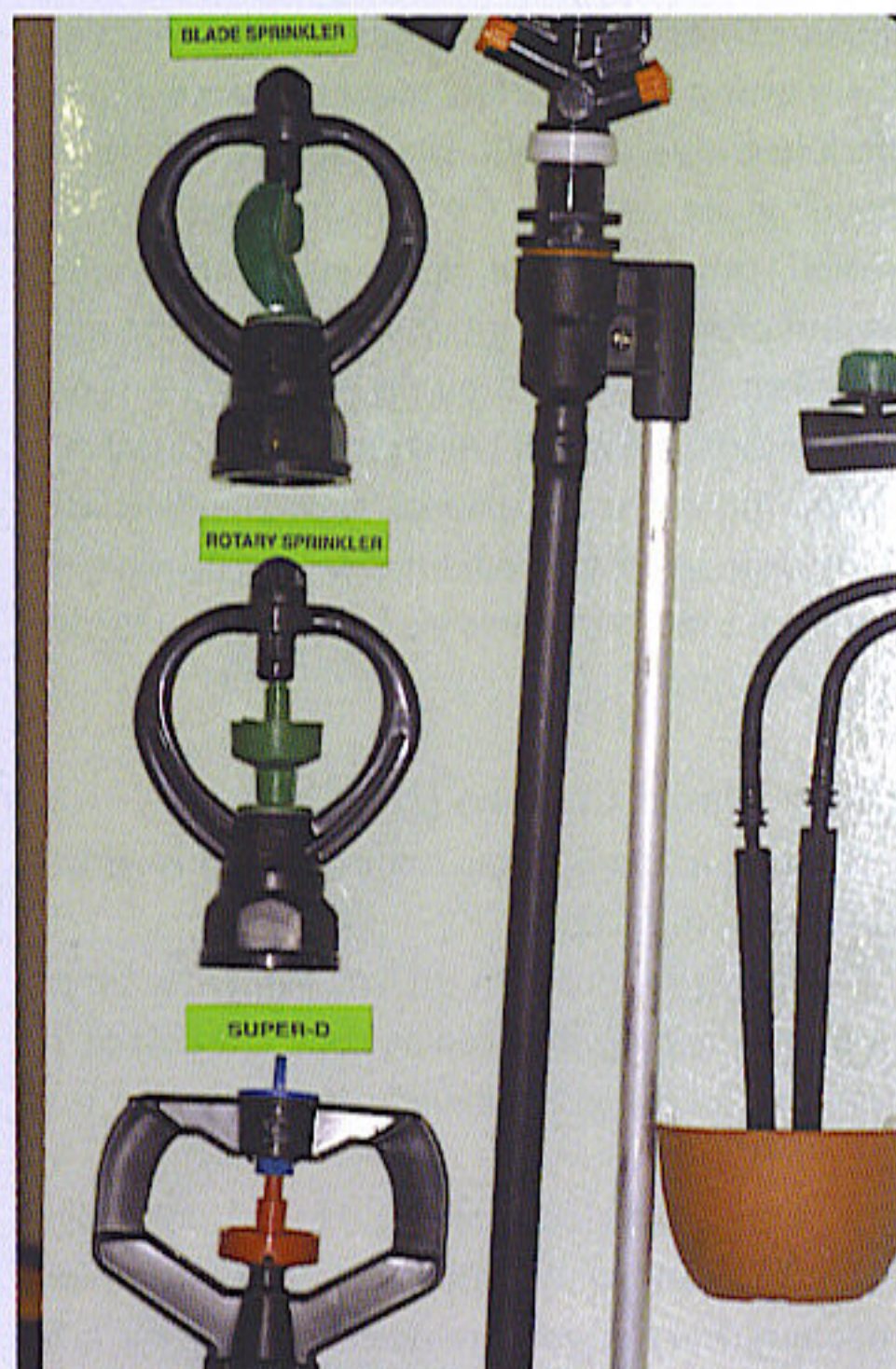
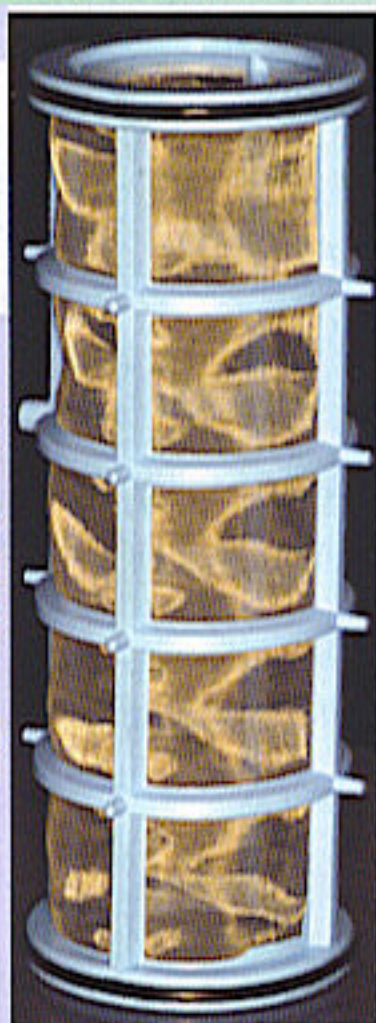
Cutaway of the inside of a DWC garden

Various emitters are available to apply nutrient solution. A single application point is common when growing in absorbent growing mediums such as rockwool and coco coir. Expanded clay works best when nutrient solution is applied via a large round emitter, several single emitters, or a spray emitter.

Always use a filter when using emitters. The filter will remove foreign objects that plug emitters.



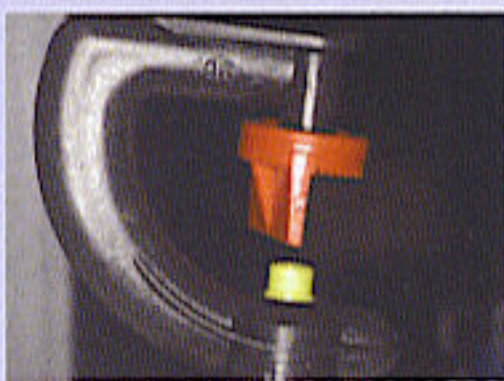
Circular emitters apply nutrient solution all the way around the plant, so all roots receive adequate moisture.



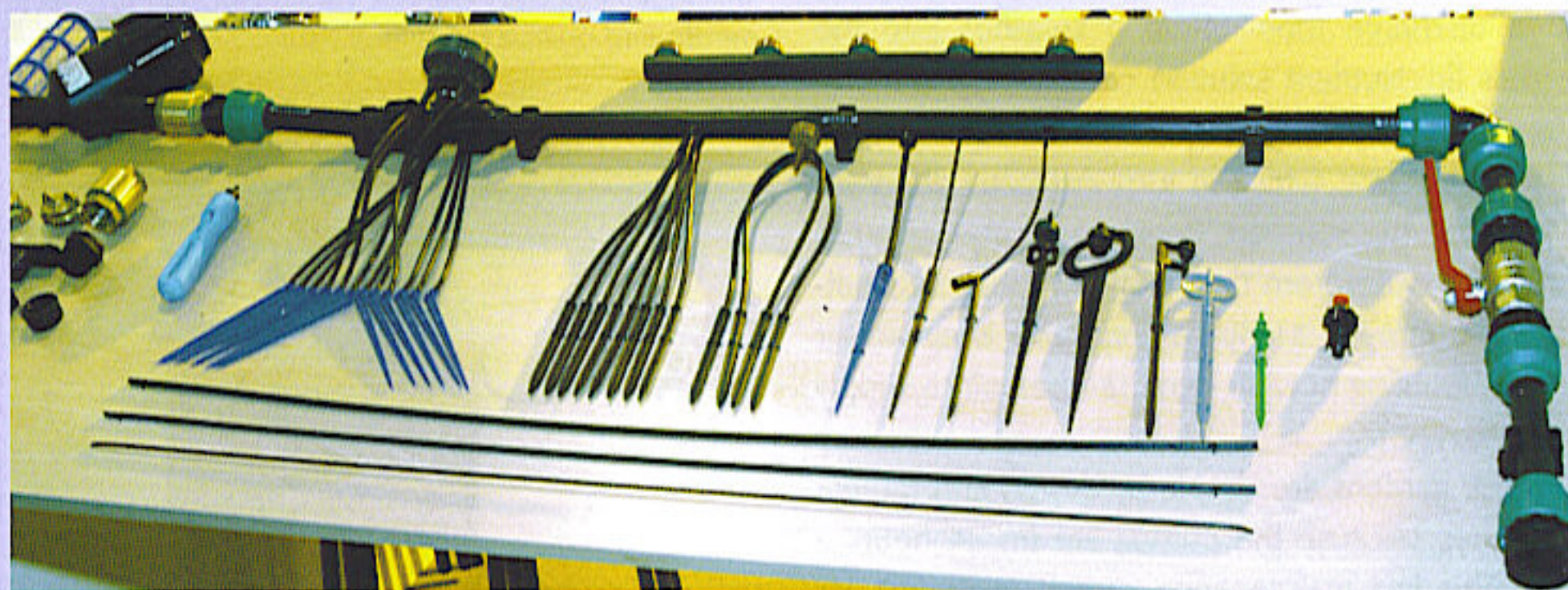
Mini sprinkler emitters are available in many sizes and outputs.



Pressure regulated drip emitters control solution flow.



This emitter sprays nutrient solution over the top of the growing medium to aerate and disperse it evenly.



An array of different emitters connected to a main manifold shows the many different kinds of emitters available to hydroponic gardeners. Across the bottom are three different diameters of spaghetti tubes that dispense three different volumes of nutrient solution to plants.

Top-Feed Systems

Top-feed hydroponic systems are very productive, easy to control, precise, easy to maintain, and efficient. The nutrient solution is metered out in specific doses and delivered via spaghetti tubing or an emitter placed at the base of individual plants. Aerated nutrient solution flows into the growing medium and is taken up by roots. The runoff nutrient solution is directed back to the reservoir as soon as it drains from the growing medium. Rockwool, gravel, coconut coir, and expanded clay are the most common growing mediums found in top-feed systems. Versatile top-feed systems can be used with individual containers or slabs in individual beds or lined up on tables.

Top-feed systems come in many configurations. Systems with several gallons of growing medium are best for growing large plants that may require support. Small containers are perfect for smaller plants.

Top-Feed Buckets

Self-contained top-feed buckets consist of a growing container nested inside a reservoir containing a pump. Individual buckets make culling out and replacing a sick plant quick and easy. Self-contained top-feed bucket systems are also perfect for growing large mother plants. The container can be moved anywhere easily. Some containers have a net pot suspended in the lid of a five-gallon (19 L) bucket/reservoir. The roots hang down into the reservoir. An air stone in the bottom of the reservoir aerates the nutrient solution. A separate pump cycles the irrigation to the container. Other self-contained top-feed buckets use a large growing container filled with expanded clay pellets. A pump constantly cycles nutrient solution in the system, aerating the solution and irrigating the plant. Roots grow down into the nutrient solution to form a mass on the bottom. Irrigation from the top circulates aerated nutrient solution and flushes out old oxygen-poor solution. Some systems contain a one-inch (3 cm) pipe to draw air directly down to the root zone. There are many different variations of this system, and they all work!



These top feed buckets filled with hydroclay are all set up and ready to be planted. More hydroclay will be added when clones are transplanted.



The grower plants three well-rooted cuttings in each container.

Multiple Bucket Top-Feed

Other top-feed bucket systems employ multiple buckets that are connected to a main reservoir. A flexible drain hose is attached near the bottom of the bucket/reservoir. The hose is connected to a drainage manifold that shuttles runoff nutrient solution back to a central reservoir.

Each reservoir below the growing container holds an inch or two of water. It is important to regularly cycle irrigation in these gardens, so the solution in the bottom of the buckets does not stagnate.

Top-feed buckets can also be lined up on a drainage table. Square containers make most efficient use of space. Plants are fed with irrigation tubing attached to a manifold. Once delivered, the nutrient solution flows and percolates through the growing medium. Roots take in the aerated nutrient solution before it drains onto the tray and back to the reservoir.



Containers are irrigated with spaghetti tubes attached to a manifold that runs between the rows. Excess nutrient solution drains out the bottom and is directed back to the reservoir via a drain tube.



This cutaway of a top-feed bucket system shows how roots dangle in a 100 percent humid environment before growing into the nutrient solution. Remember to screen the drain in the reservoir so roots do not block it.

Individual containers in top-feed bucket systems are easy to arrange to fit into the allotted garden space. Plants can also be transplanted or removed from pots and cared for individually.

Top-Feed Slabs

Overview

Top-feed slab systems are popular among small and large indoor and greenhouse growers. Rockwool or coco slabs covered in plastic serve as growing containers. The nutrient solution is delivered via spaghetti tubes from the top of the slab. An emitter attached to the spaghetti tube doses a specific measure of nutrient solution to each plant. The nutrient solution is aerated as it is applied, before being absorbed by the growing medium and draining back to the reservoir.

A simple nutrient solution delivery manifold consists of emitters connected to spaghetti delivery tubes. The tubes are attached to a short manifold that is fed by a pump submerged in a reservoir.

Emitters are designed to be anchored in growing medium and to emit a measured dose of nutrient solution.

Slabs in individual trays

Some systems use individual trays to contain slabs. Nutrient solution is pumped from the reservoir and delivered to plants via spaghetti tubes attached to emitters. Individual trays are easy to configure for different sized gardens.

Tables of slabs

You can also set up a drainage table and place slabs on top. The nutrient solution is pumped from the reservoir below the table and delivered to individual plants via spaghetti tubes attached to emitters. The solution flows into the growing medium where it comes into contact with roots. Excess nutrient solution drains from pots onto the table and is carried back to the reservoir. Make sure the table is set up on an incline so it drains evenly. Pockets of standing water on the table contain less oxygen and promote rot.

Individual Blocks

Individual blocks in this rockwool system allow gardeners the possibility of removing or changing plants if necessary. Nutrient solution is pumped via

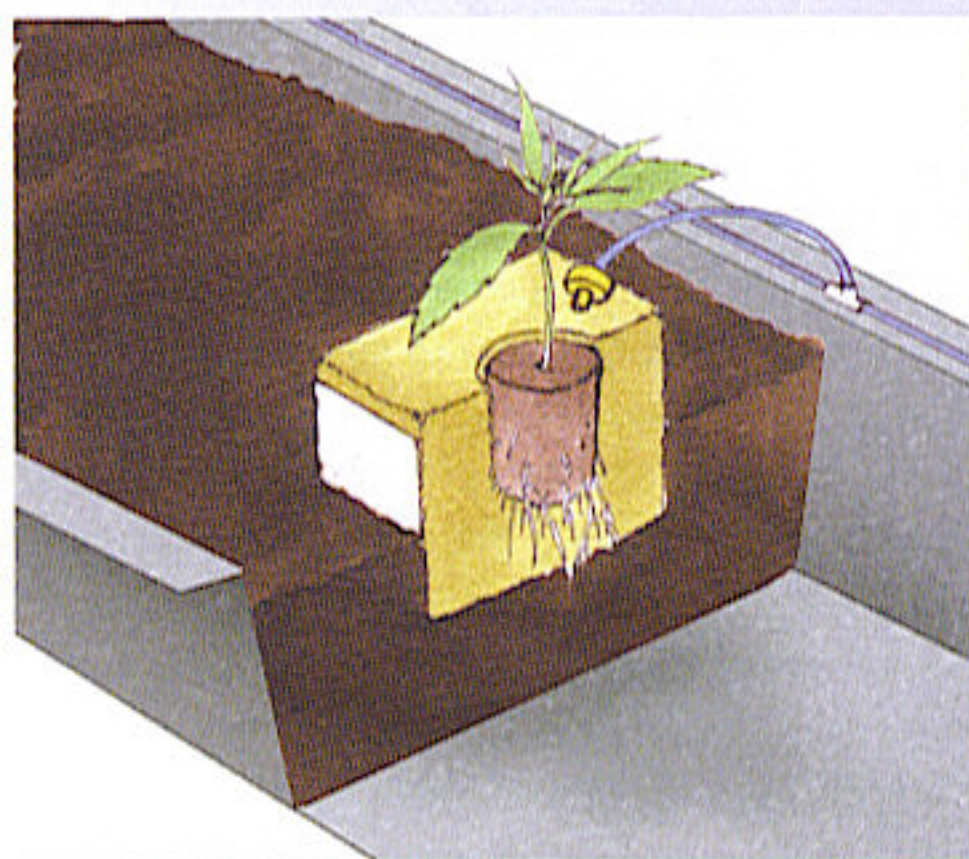
spaghetti tubes from the reservoir below and distributed via emitters pressed into rockwool cubes.

Vertical Top-Feed Systems

Vertical gardens can increase overall yield more than ten-fold over a flat garden. Substrate bags, tubes, or slabs are positioned vertically around an HID. Short plants are placed in the medium and fed individually with a drip emitter. The runoff drains through the growing medium and back to the reservoir. The solution is re-circulated once it returns to the reservoir.



Top-feed slabs of rockwool fit in individual containers. Spaghetti tubes irrigate plants from the top.



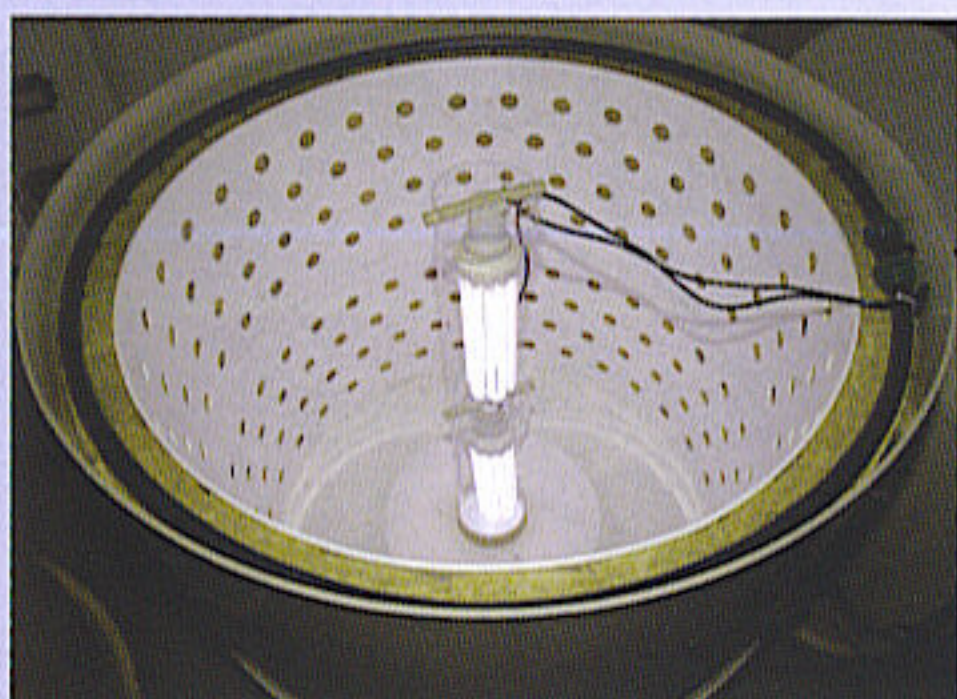
This cutaway drawing shows how nutrient delivery is simple and easy with a top-feed bat system. Aerated nutrient solution is metered via emitter onto a grow cube. Aerated solution percolates down through the medium. Channels in the bottom of the tray speed drainage back to the reservoir.



Nutrient solution from this bat of Canna coco drains into an open trough and is carried back to the reservoir. Salt buildup from the nutrient solution is easy to scrub out of the open trough.



Ebb and flow tables catch nutrient solution runoff and direct it back to the reservoir.



This new vertical garden uses rockwool as a growing medium and compact fluorescent lamps.

Use rockwool or coco mixed with lightweight vermiculite as a growing medium to lessen weight when substrate is wet. Irrigate constantly to keep roots supplied with water and nutrients from a well-aerated solution.

Vertical hydroponic systems save space, but require more maintenance. These systems can also be tricky to fine-tune so they operate at peak capacity.

NFT

Nutrient Film Technique (NFT) hydroponic systems are high performance gardens that perform well when fine-tuned. This relatively new form of hydroponics supplies aerated nutrient solution to roots located in gullies. Seedlings or cuttings with a strong root system are placed on capillary matting located on the bottom in a covered channel. The capillary matting stabilizes nutrient solution flow and holds roots in place. Constantly aerated nutrient solution flows down the channel, or gully, over and around the roots, and back to the reservoir. Irrigation is most often constant, 24 hours a day. Roots receive plenty of oxygen and are able to absorb a maximum of nutrient solution. Proper gully incline, volume, and flow of nutrient solution are key elements in NFT gardens.

Gullies or channels are covered to keep humidity high in the root zone and light from shining on roots. Root hairs responsible for most water and nutrient uptake cover the growing tips of advancing roots. These roots are submerged in turbulently

flowing nutrient solution and the tops are intermittently in humid air. The nutrient solution is constantly aerated as it flows down the inclined gully. The slope of the gully is adequate to prevent water from stagnating. Often a filter is necessary to prevent debris from blocking gullies and pump.

Although high performance, NFT systems offer practically no buffering ability. In the absence of a growing medium, roots must be kept perfectly moist by the nutrient solution at all times. If a pump fails, roots dry and die. If the system dries out for a day or longer, small feeder roots will die and grave consequences will result. The system is very easy to clean and lay out after each crop. Only growers with several years experience should try an NFT system if working alone. With help, they are easier to master.

Double reinforced bottom makes gullies durable and rigid when supporting large plants, root systems, and large volumes of nutrient solution. Some NFT gullies have ribs below to provide support and prevent warping and movement. The ribs also function as drainage channels and direct nutrient solution evenly along the bottom of the gully.

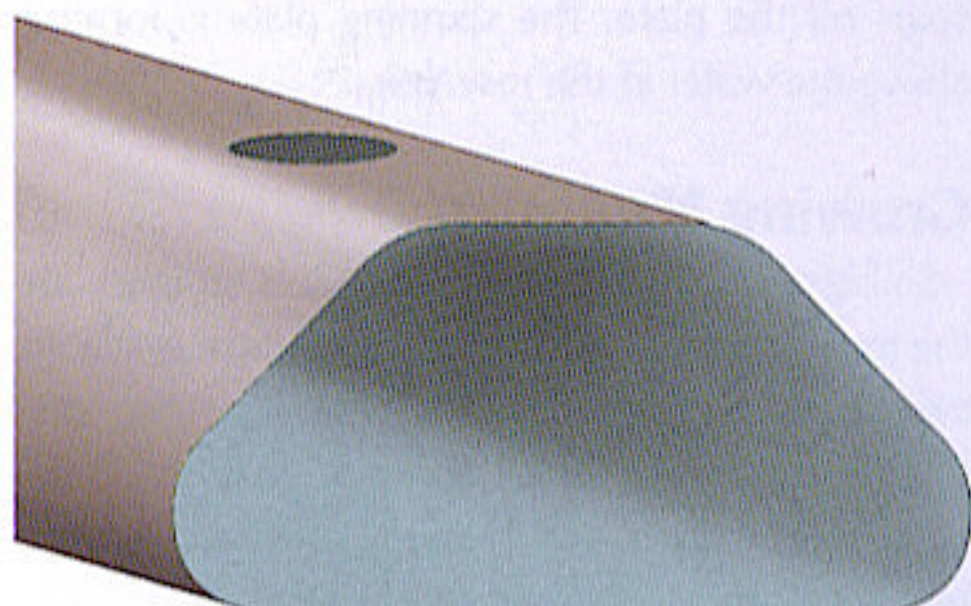
Many NFT systems are hybrids. For example, the nutrient solution in some hybrid NFT systems is delivered via spaghetti tubing to each plant. More irrigation sites help each plant receive proper irrigation. The nutrient solution flows through a small basket of growing medium before it runs down the gully, over the roots, and back to the reservoir. Yet another hybrid NFT system employs spray nozzles inside the gully. The nozzles spray nutrient solution on and around roots to keep the root zone environment at 100 percent humidity. The nutrient solution flows down a PVC pipe, over roots, and back to the reservoir.

Too often, these hybrid systems are poorly planned and designed. Many times they are constructed from white four-inch PVC pipe. The thin white walls of the PVC pipe allow enough light to illuminate roots that they turn green or rot more easily. I have also seen systems with nozzles inside the PVC pipe. If a nozzle plugged inside the pipe, there was no easy way to access the nozzle for maintenance.

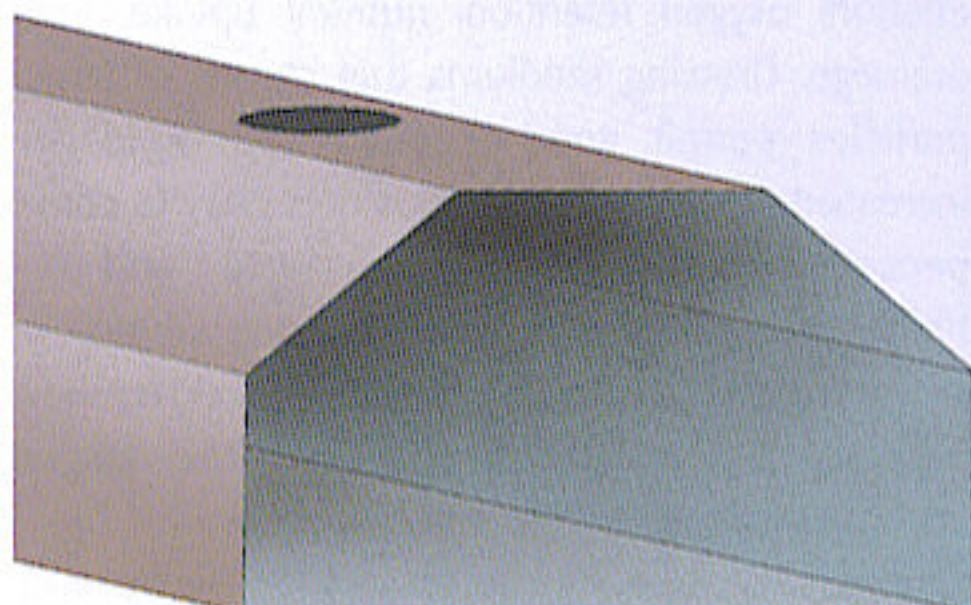
Nutrient solution is pumped from the reservoir into gullies via a manifold and tubing at the upper end. The table is set up on an incline so the nutrient solution flows quickly over roots to create an environment packed with air and available nutrients. A catchment drain directs the nutrient back into the nutrient reservoir.

Aeroponics

Aeroponic systems use no growing medium and offer the highest performance possible. Roots are suspended in a dark growth chamber without growing medium where they are misted with oxygen-rich nutrient solution at regular intervals. The humidity in the chamber remains at or near 100 percent 24 hours a day. Roots have the maximum potential to absorb nutrient in the presence of air.



Gullies with rounded corners are very popular in Australia. Growers who use them say the nutrient solution flows more smoothly.



Many gullies are flat on the bottom. Capillary matting is placed on the bottom under the growing cubes. The capillary matting anchors roots and helps direct nutrient solution evenly over roots.



Small net pots are preferred for most NFT systems. Larger net pots are used in NFT systems as well as top-feed hydroponic systems.



Nutrient solution in this hybrid NFT system is delivered via nozzles attached to a PVC pipe inside the main growing tubes.



Stagnant nutrient solution and salt buildup stifle root development. Soon roots turn dark and rot. Note burned and discolored leaves that signify salt buildup.



Roots in this NFT system are strong and healthy. This system produced a heavy harvest of buds on robust plants.



Long root systems develop quickly on cuttings in this Rain Forest aeroponic system.



Rooted clones and seedlings grown in aeroponic systems develop exceptionally fast. To grow clones, simply insert clone stems into the growth chamber and turn it on. The roots will grow in a perfect environment to develop roots.

Humid air and nutrient solution are all that fill the growth chamber. Plants are most often grown in net pots full of growing medium and suspended from the top of the system.

Aeroponic systems require greater attention to detail. There is no growing medium to act as a water/nutrient bank, which makes the system delicate and touchy to use. If the pump fails, roots soon dry, and plants suffer. Systems that use delicate spray nozzles must be kept free of debris. Imbalanced nutrient solution and pH can also cause problems quickly. This is why it is important to purchase quality components or a ready-made system from a qualified supplier.

The RainForest (www.generallyhydroponics.com) is very popular. Nutrient solution is actually atomized into the air creating 100 percent humidity. Nutrient solution is dripped onto a spinning plate. The solution atomizes, mixing with the air as it spins off the plate. The spinning plate is located above the water in the reservoir.

Growing Mediums

Soiless growing mediums provide support for the root system, as well as hold and make available oxygen, water, and nutrients. Three factors contribute to cannabis roots' ability to grow in a substrate: texture, pH, and nutrient content, which is measured in EC, electrical conductivity.

The texture of any substrate is governed by the size and physical structure of the particles that constitute it. Proper texture promotes strong root penetration, oxygen retention, nutrient uptake, and drainage. Growing mediums that consist of large particles permit good aeration and drainage. Increased irrigation frequency is necessary to compensate for low water retention. Water- and air-holding ability and root penetration are a function of texture. The smaller the particles, the closer they pack together and the slower they drain. Larger particles drain faster and retain more air.

Irregular shaped substrates such as perlite and some expanded clays have more surface area and hold more water than round soiless mediums. Avoid crushed gravel with sharp edges that cut into roots if the plant falls or is jostled around. Round

pea gravel; smooth, washed gravel; and lava rocks are excellent mediums to grow marijuana in an active recovery system. Thoroughly wash clay and rock growing mediums to get out all the dust that will turn to sediment in your system.

Fibrous materials like vermiculite, peat moss, rockwool, and coconut coir retain large amounts of moisture within their cells. Such substrates are ideal for passive hydroponic systems that operate via capillary action.

Mineral growing mediums are inert and do not react with living organisms or chemicals to change the integrity of the nutrient solution. Coconut coir and peat mosses are also inert.

Non-inert growing mediums cause unforeseen problems. For example, gravel from a limestone quarry is full of calcium carbonate, and old concrete is full of lime. When mixed with water, calcium carbonate will raise the pH, and it is very difficult to make it go down. Growing mediums made from reconstituted concrete bleed out so much lime, they soon kill the garden.

Avoid substrates found within a few miles of the ocean or large bodies of salt water. Most likely, such mediums are packed with toxic salts. Rather than washing and leaching salts from the medium, it is easier and more economical to find another source of substrate.

Air is a great medium when it is filled with 100 percent humidity 24 hours a day.

Coconut fiber is an excellent hydroponic medium. See "Coconut Fiber" under soil amendments. Hit the site www.canna.com for detailed information about growing marijuana in coconut fiber.

Expanded clay, also called hydroclay, or hydrocorn, is made by many different manufacturers. The clay pellets are cooked at high temperatures in a kiln until they expand. Many little catacomb-like pockets form inside each pellet that holds air and nutrient solution. It is an excellent medium to mix with Peat-Lite and to grow mothers in large containers. I like the way it drains so well and still retains nutrient solution while holding lots of oxygen. Examples of expanded clay include commercially available Hydroton, Leca, Grorox, Geolite.



Coco is compressed into slabs and packaged in plastic. Add water to expand coco to full size.



Coconut fiber is also available in bags.



Expanded clay holds moisture and nutrients along with lots of oxygen.



Artificial foam slabs are used by some growers. To date they are still gaining popularity.



Pumice is a good growing medium. It can also be used as mulch or as an inert soil amendment.



Peat moss mixed with perlite is one of the all-time favorite growing mediums. It is also an excellent soil amendment.



Perlite is sand or volcanic glass expanded by heat. See Chapter Ten for more information.

Grow Rocks

Some clay pellets will float.

Expanded clay can be reused again and again. Once used, pour expanded clay pellets into a container and soak in a sterilizing solution of ten milliliters hydrogen peroxide per four liters of water. Soak for 20-30 minutes. Remove expanded clay and place on a screen of hardware cloth. Wash and separate clay pellets from dead roots and dust. Let dry and reuse.

Expanded mica is similar to expanded clay. For lots of exacting information on how and why this stuff works so well, check out www.hydroponics.com.

Foam is somewhat popular. It lasts a long time, lends itself to easy sterilization, and holds a lot of water and air.

Gravel is one of the original hydroponic mediums. Although heavy, gravel is inert, holds plenty of air, drains well, and is inexpensive. Still popular today, gravel is difficult to over-water. It holds moisture, nutrient, and oxygen on its outer surfaces. Use pea gravel or washed river gravel with round edges that do not cut roots when jostled about. Gravel should be 0.125-0.375-inches (3-10 mm) in diameter, with more than half of the medium about 0.25-inch (6 mm) across. Crushed rock can be packed with many salts. Pre-soak and adjust its pH before use. Gravel has low water retention and low buffering ability.

Pumice is a naturally occurring, porous, lightweight, volcanic rock that holds moisture and air in catacomb-like surfaces. Light and easy to work with, some lava rock is so light it floats. Be careful that sharp edges on the rocks do not damage roots. Lava rock is still a good medium and acts similarly to expanded clay. See "Pumice" under "Soil Amendments."

Peat moss is partially decomposed vegetation. Decomposition has been slow in the northern regions where it is found in bogs. There are three common kinds of peat moss—Sphagnum, Hypnum, and Reed/Sedge. Sphagnum peat is about 75 percent fiber with a pH of 3 to 4. Hypnum peat is about 50 percent fiber with a pH of about 6. Reed/sedge peat is about 35 percent fiber with a pH of six or more. For more information see "Soil Amendments" in Chapter Ten.

Perlite drains fast, but it's very light and tends to float when flooded with water. Perlite has no buffering capacity and is best used to aerate soil or soilless mix. See "Soil Amendments" in Chapter Ten.

Rockwool is an exceptional growing medium and a favorite of many growers. It is an inert, sterile, porous, non-degradable growing medium that provides firm root support. Rockwool

has the ability to hold water and air for the roots. The roots are able to draw in most of the water stored in the rockwool, but it has no buffering capacity and a high pH. Rockwool is probably the most popular hydroponic growing medium in the world. Popular brand names include Grodan, HydroGro and Vacrok.

Sand is heavy and has no buffering ability. Some sand has a high pH. Make sure to use sharp river sand. Do not use ocean or salty beach sand. Sand drains quickly but still retains moisture. Sand is best used as a soil amendment in volumes of less than ten percent.

Sawdust holds too much water for marijuana growth and is usually too acidic. Be wary of soils with too much wood matter. Such mediums use available nitrogen to decompose the leglin in the wood.

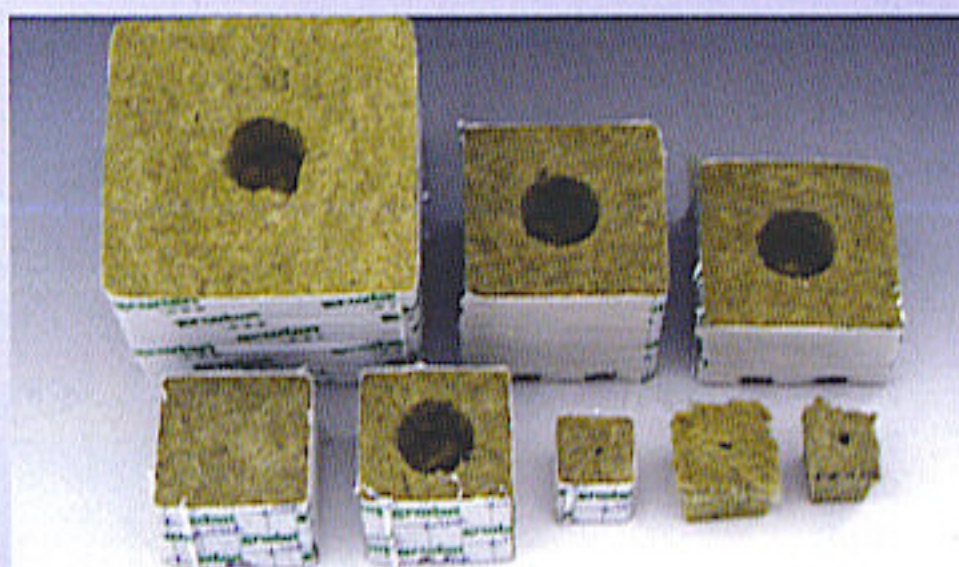
Vermiculite holds a lot of water and is best suited for rooting cuttings when it is mixed with sand or perlite. With excellent buffering qualities, vermiculite holds lots of water and has traces of magnesium (Mg), phosphorus (P), aluminum (Al), and Silicon (Si). Do not use construction grade vermiculite which is treated with phytotoxic chemicals. See "Soil Amendments" in Chapter Ten for more information.

Water alone is a poor medium, because it cannot hold enough oxygen to support plant life. When aerated, water becomes a good growing medium.

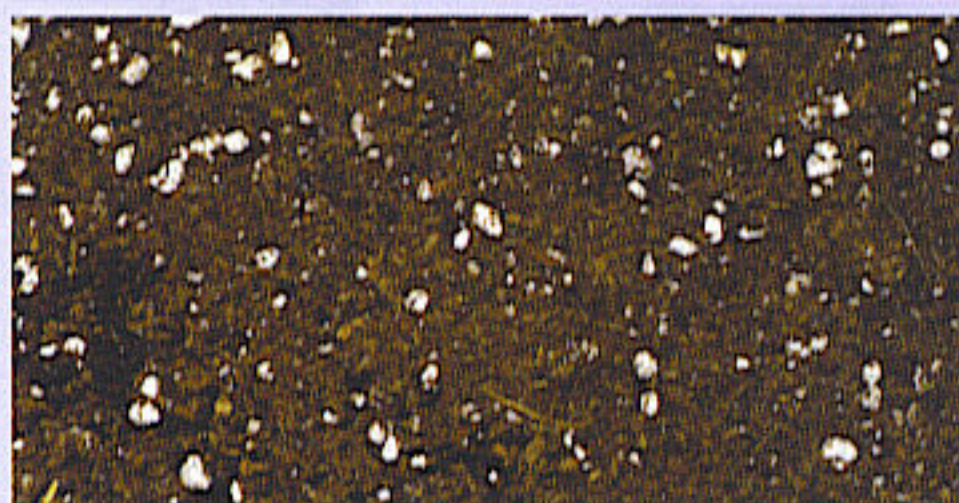
pH

The pH of the nutrient solution controls the availability of ions that cannabis needs to assimilate. Marijuana grows well hydroponically within a pH range of 5.5-6.5, with 5.8-6.0 being ideal. The pH in hydroponic gardens requires a somewhat vigilant eye. In hydroponics, the nutrients are in solution and more available than when in soil. The pH of the solution can fluctuate a half point and not cause any problems.

Roots take in nutrients at different rates, which causes the ratios of nutrients in solution to change the pH. When the pH is above 7 or below 5.5, some nutrients are not absorbed as fast as possi-



Rockwool cubes hold plenty of air and nutrient solution within their fiber; plus, they are clean and easy to use.



Soilless grow medium.



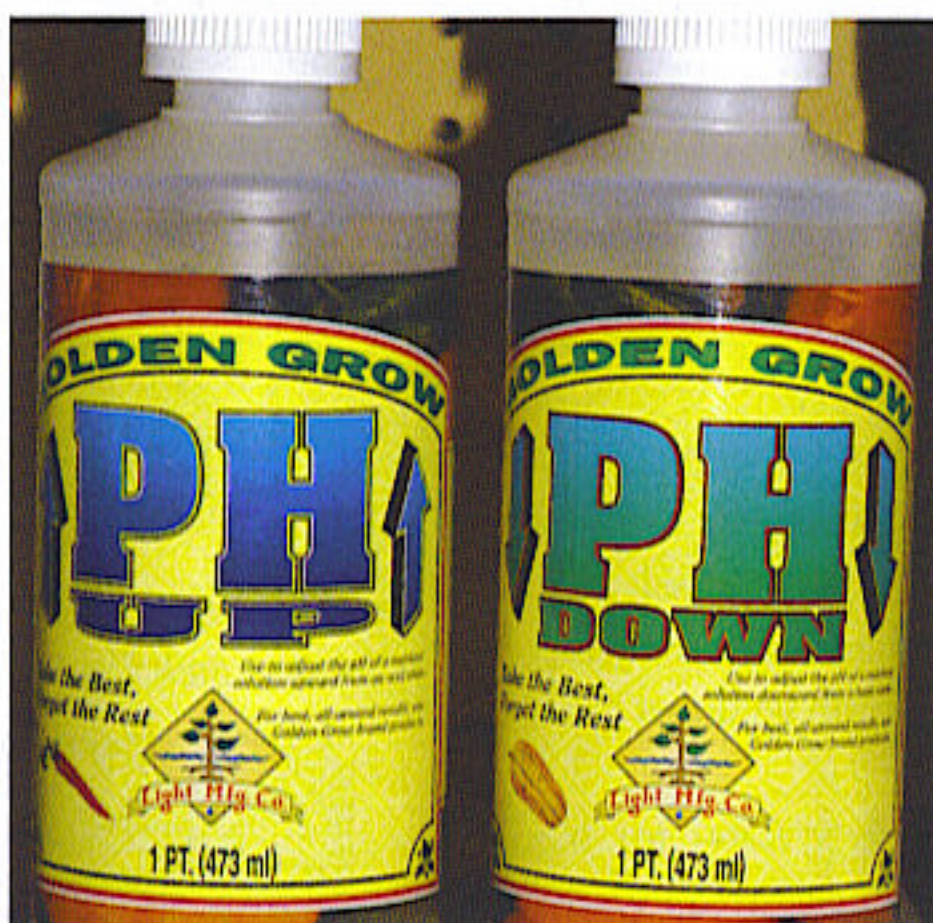
Vermiculite holds a lot of nutrient solution.

This chart shows the porosity and air space available in different substrates.

	Substrate Porosity	Air Space
Coconut fiber	90%	10%
Peat/Vermiculite	88%	9%
Peat/Perlite	78%	15%
Peat/Rockwool	88%	14%
Peat moss	90%	15%
Perlite	68%	30%
Rockwool	90%	20%
Sand	38%	3%
Vermiculite	80%	10%

Buy pH Up and pH Down rather than making your own from concentrated acids. Commercial mixes are buffered and safe to use.

Adjust nutrient solution pH level up with:
pH Up
 Potassium hydroxide
 Do not use dangerous and caustic sodium hydroxide to raise pH.



Adjust nutrient solution pH level down with:
pH Down
 Nitric acid
 Phosphoric acid
 Citric acid
 Vinegar



This controller monitors and controls the pH in the reservoir by dispersing pH Up or pH Down. The separate thermometer/hygrometer on top of the controller in the photo monitors ambient temperature and humidity.

ble. Check the pH every day or two to make sure it is at or near the perfect level.

Deviations in pH levels often affect element solubility. Values change slightly with different plants, grow mediums, and hydroponic systems. Overall, hydroponic gardens require lower pH levels than that of soil. The best pH range for hydroponic gardens is from 5.5 to 6.5. Different mediums perform best at different pH levels. Follow manufacturer's guidelines for pH level, and correct the pH using the manufacturer's suggested chemicals, because they will react best with their fertilizer.

The pH can easily fluctuate up and down one full point in hydroponic systems and cause little or no problem with nutrient uptake.

Follow the directions on the container, and remember to mix adjusters into the reservoir slowly and completely. Fertilizers are normally acidic and lower the pH of the nutrient solution. But nutrient solution is still taken in by plants, and water transpires and evaporates into the air, which causes the pH to climb.

Stabilize the pH of the water before adding fertilizer.

Make a correction if readings vary $\pm$ one-half point.

EC, TDS, DS, CF, PPM

EC METERS

Pure distilled water has no resistance and conducts no electrical current. When impurities are added to pure distilled water in the form of fertilizer salts, it conducts electricity. A water analysis will indicate the impurities or dissolved solids found in household tap water. These impurities conduct electricity.

Nutrient (salt) concentrations are measured by their ability to conduct electricity through a solution. Dissolved ionic salts create electrical current in solution. The main constituent of hydroponic solutions is ionic salts. Several scales are currently used to measure how much electricity is conducted by nutrients including: Electrical Conductivity (EC), Conductivity Factor (CF), Parts Per Million (ppm), Total Dissolved Solids (TDS), and Dissolved Solids (DS). Most American growers use ppm to measure overall fertilizer concentration. European, Australian, and New Zealand growers use EC, however they still use CF in parts of Australia and New Zealand. Parts per million is not as accurate or consistent as EC to measure nutrient solution strength.

The difference between EC, CF, ppm, TDS, and DS is more complex than originally meets the eye. Different measurement systems all use the same base, but interpret the information differently. Let's start with EC, the most accurate and consistent scale.

Electrical conductivity is measured in milliSiemens per centimeter (mS/cm) or microSiemens per centimeter (µS/cm). One microSiemen/cm = 1000 milliSiemens/cm.

Parts per million testers actually measure in EC and convert to ppm. Unfortunately, the two scales (EC and ppm) are not directly related. Each nutrient or salt gives a different electronic discharge reading. To overcome this obstacle, an arbitrary standard was implemented which assumes "a specific EC equates to a specific amount of nutrient solution." Consequently, the ppm reading is not precise; it is only an approximation, a ball park figure! It gets more complex! Nutrient tester manufacturers use different standards to convert from EC to the ppm reading.



ABOVE LEFT: The probe of this meter is submerged in the nutrient solution to monitor pH 24 hours a day.

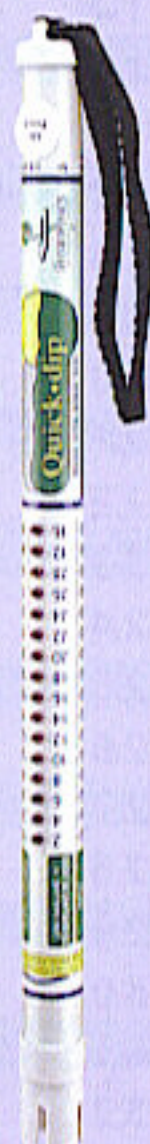


ABOVE RIGHT: Constant read-out, temperature-compensated EC/ppm meters with a probe immersed in the nutrient tank provide round-the-clock intelligence.

RIGHT: This quick-dip Thrugeon measures EC quickly and efficiently. It was one of the first accurate, economical EC meters that was easy to use.

Every salt in a multi-element solution has a different conductivity factor. Pure water will not conduct electrical current, but when elemental salts/metals are added, electrical conductivity increases proportionately. Simple electronic meters measure this value and interpret it as total dissolved solids (TDS). Nutrient solutions used

EC = Electrical Conductivity
CF = Conductivity Factor
PPM = Parts Per Million
TDS = Total Dissolved Solids
DS = Dissolved Solids



- 1. Hanna 1 mS/cm = 500 ppm
- 2. Eutech 1 mS/cm = 640 ppm
- 3. New Zealand Hydro. 1 mS/cm = 700 ppm

Parts per million recommendations are inaccurate and confusing. To help you through this confusion, an Australian friend compiled the following easy reference conversion chart.

1 mS/cm = 10 CF e.g. 0.7 EC = 7 CF

Conversion scale from ppm to CF and EC.

EC mS/cm	Hanna 0.5ppm	Eutech 0.64ppm	Truncheon 0.70ppm	CF 0
0.1	50	64	70	01
0.2	100	128	140	02
0.3	150	192	210	03
0.4	200	256	280	04
0.5	250	320	350	05
0.6	300	384	420	06
0.7	350	448	490	07
0.8	400	512	560	08
0.9	450	576	630	09
1.0	500	640	700	10
1.1	550	704	770	11
1.2	600	768	840	12
1.3	650	832	910	13
1.4	700	896	980	14
1.5	750	960	1050	15
1.6	800	1024	1120	16
1.7	850	1088	1190	17
1.8	900	1152	1260	18
1.9	950	1216	1330	19
2.0	1000	1280	1400	20
2.1	1050	1344	1470	21
2.2	1100	1408	1540	22
2.3	1150	1472	1610	23
2.4	1200	1536	1680	24
2.5	1250	1600	1750	25
2.6	1300	1664	1820	26
2.7	1350	1728	1890	27
2.8	1400	1792	1960	28
2.9	1450	1856	2030	29
3.0	1500	1920	2100	30
3.1	1550	1984	2170	31
3.2	1600	2048	2240	32

to grow marijuana generally range between 500 and 2000 ppm. If the solution concentration is too high, the internal osmotic systems can reverse and actually dehydrate the plant. In general, try to maintain a moderate value of approximately 800 to 1200 ppm.

Nutrient solution concentration levels are affected by nutrient absorption by roots and by water evaporation. The solution weakens as plants use nutrients, but water also evaporates from the solution, which increases the nutrient concentration. Adjust the concentration of the solution by adding fertilizer or diluting with more water.

Many factors can alter the EC balance of a solution. For example, if under-watered or allowed to dry completely, the EC reading will rise. In fact, the EC may increase to two- or three-times as high as the input solution when too little water is applied to rockwool. This increase in slab EC causes some nutrients to build up faster than others. When the EC doubles, the amount of sodium can increase as much as four- to six-fold under the right conditions! There should not be any sodium present in your

Parts per million meters measure the overall level of dissolved solids or fertilizer salts. Each fertilizer salt conducts different quantities of electricity. Use a calibrating solution that imitates the fertilizer in the nutrient solution to calibrate ppm or EC meters. Using such a solution ensures the meter readings will be as accurate as possible. For example, 90 percent of ammonium nitrate dissolved in water is measured, and a mere 40 percent of the magnesium is measured! Do not use sodium-based calibration solutions. They are intended for other applications than gardening. Purchase calibrating solution from the manufacturer or retailer when you buy the meter. Ask for a stable calibrating solution that mimics your fertilizer. Calibrate EC and ppm meters regularly. A good combination ppm, EC, pH meter that compensates for temperature costs about \$200 and is well worth the money. Batteries last a long time, too.

garden unless it is in the water supply, and it should not be in excess of 50 ppm.

Let 10-20 percent of the nutrient solution drain from the growing medium after each irrigation cycle to help maintain EC stability. The runoff carries away any excess fertilizer salt buildup in the growing medium.

If the EC level of a solution is too high, increase the amount of runoff you create with each flush. Instead of a 10-20 percent runoff, flush so 20-30 percent of the solution runs off. To raise the EC, add more fertilizer to the solution, or change the nutrient solution.

A dissolved solids (DS) measurement indicates how many parts per million (ppm) of dissolved solids exist in a solution. A reading of 1800 ppm means there are 1800 parts of nutrient in one million parts solution, or 1800/1,000,000.

An EC meter measures the overall volume or strength of elements in water or solution. A digital LCD screen displays the reading or the EC of the electrical current flowing between the two electrodes. Pure rainwater has an EC close to zero. Check the pH and EC of rainwater to find out if it is acidic (acid rain) before using it.

Distilled bottled water from the grocery store often registers a small amount of electrical resistance, because it is not perfectly pure. Pure water with no resistance is very difficult to obtain and not necessary for a hydroponic nutrient solution.

Electrical conductivity measurement is temperature-sensitive and must be factored into the EC reading to retain accuracy. High-quality meters have automatic and manual temperature adjustments. Calibrating an EC meter is similar to calibrating a pH meter. Simply follow manufacturer's instructions. For an accurate reading, make sure your nutrient solution and stock solution are the same temperature.

Inexpensive meters last for about a year, and expensive meters can last for many years. However, the life of most EC meters, regardless of cost, is contingent upon regular maintenance. The probes must be kept moist and clean at all times. This is the most important part of keeping the meter in good repair. Read instructions on care and maintenance.

Watch for corrosion buildup on the probes of your meter. When the probes are corroded, readings will not be accurate.

To check the EC of the nutrient solution, collect samples from both the reservoir and the growing medium. Save time and effort; collect EC and pH samples simultaneously. Collect samples with a syringe or baster at least two inches deep into the rockwool and coco. Collect separate sample from the reservoir. Place each sample in a clean jar. Use calibrated EC meter to measure the samples. Under normal conditions, the EC in the slab should be a little higher than the nutrient solution in the reservoir. If the EC of the solution drawn from the growing medium is substantially higher than the one from the reservoir, there is a salt buildup in the substrate. Correct the imbalance by flushing substrate thoroughly with diluted nutrient solution, and replace with new solution. Regularly check the EC of your water, slab, and runoff.

Sterilizing

To reuse a growing medium, it must be sterilized to remove destructive pests and diseases. Sterilizing is less expensive and often easier than replacing the growing medium. Sterilizing works best on rigid growing mediums that do not lose their shape such as gravel, expanded clay, and mica. Avoid sterilizing and reusing substrates that compact and lose structure such as rockwool, coconut coir, peat moss, perlite, and vermiculite. Avoid problems caused by compaction and dead roots by replacing used growing mediums. Once sterilized, the medium is free of harmful microorganisms including bacteria and fungi, plus pests and their eggs.

Remove roots from the growing medium before sterilizing. A three- to four-month-old marijuana plant has a root mass about the size of an old desk telephone. Separate the medium by shaking and pulling roots away. Bounce the medium on a screen so roots come to the top. Scoop up and remove roots by hand. Fewer decaying roots cause fewer pest and disease problems, and decrease incidence of clogged feeder tubes.



Remove harvested plant root balls from the growing medium, and remove roots and stems.



Wash substrate with plenty of fresh water to remove built-up salts and dead roots.

Substrate can also be washed in a large container such as a barrel or bathtub. Washing works best with lighter substrates such as expanded clay or mica. Roots float to the top and are readily skimmed off with a screen or by hand.

Once roots are removed, soak the substrate in a sterilant such as a five percent laundry bleach (calcium or sodium hypochlorite) solution for at least an hour. Or mix hydrochloric acid, the kind used in hot tubs and swimming pools. Pour, drain, or pump off the sterilant, and flush the medium with plenty of fresh water. A bathtub and a shower nozzle on a hose are perfect for washing substrate. Place the substrate in the bathtub, set a screen over the drain, and use the showerhead or a hose to wash down the medium. It may be necessary to fill the tub with fresh water and drain it a couple of times to rinse any residual sterilants from the substrate.

If you decide to use rockwool or coco a second time, you may have problems with pests and diseases. In general, I recommend reusing a medium only if it does not deteriorate or compact. Examples include: pea gravel, expanded clay, lava rock, sand, etc. Once used indoors, reuse rockwool and biodegradable coco in the outdoor garden.

To sterilize a hydroponic garden, remove the nutrient solution from the reservoir. Pump the solution into the outdoor garden. Avoid pumping it down household drains, and definitely do not pump it into a septic tank. The nutrients will disrupt the chemistry!

Flood the growing medium with the sterilizing solution for at least one-half hour, let drain, and flush again. Pump the bleach solution out of the system and down the drain. Do not dump sterilants outdoors; they will defoliate plants where they are dumped. Use lots of fresh water to leach and flush the entire system including beds, connecting hoses, drains, and reservoir. Make sure all residues are gone by flushing entire system twice for a half-hour. Remove all solution from the tank, and scrub away any visible signs of salt buildup with a big soapy sponge. Have a bucket of clean water handy to rinse the sponge.

An alternate sterilization method is to "solarize" the rockwool. In a sunny location, set dry slabs of rockwool outside on a sheet of black plastic, and cover with black plastic. Let the sun bake the layer of slabs, or flock, for several days. The temperatures in the rockwool will climb to 140°F (60°C) or more, enough to sterilize for most all harmful diseases and pests.

Hydroponic Nutrients

High quality hydroponic formulations are soluble, contain all the necessary nutrients, and leave no impure residues in the bottom of the reservoir. Always use the best hydroponic fertilizer you can find. There are many excellent commercial hydroponic fertilizers that contain all the nutrients in a balanced form to grow great cannabis. Quality hydroponic fertilizers packed in one, two, or three-part formulas have all the necessary macro- and micronutrients for rapid nutrient assimilation and growth. Cheap fertilizers contain low-quality, impure components that leave residue and sediments. These impurities build up readily and cause extra maintenance. High-quality, soluble hydroponic nutrients properly applied are immediately available for uptake. Exact control is much easier when using pure high-grade nutrients. Many companies use food-grade nutrients to manufacture their fertilizer formulations.

Nutrients are necessary for marijuana to grow and flourish. These nutrients must be broken down chemically within the plant, regardless of origin.

The nutrients could be derived from a natural organic base which was not heated or processed to change form, or they could be simple chemical elements and compounds. When properly applied, each type of fertilizer, organic or chemical, theoretically produces the same results.

For a complete background on nutrients and fertilizers, see Chapter Eleven, "Water and Nutrients." Many of the same principles that apply to soil apply to the hydroponic medium.

Nutrient Solutions

To avoid nutrient problems, change the nutrient solution in the reservoir every week. Change nutrient solution every two weeks in systems with a large reservoir. Change the nutrient solution more often when plants are in the last stages of flowering, because they use more nutrients. You can wait to change the nutrient solution, but imbalances are more common. Plants absorb nutrients at different rates, and some of them run out before others, which can cause more complex problems. The best form of preventive maintenance is to change the solution often. Skimping on fertilizer can cause stunted growth. Nutrient imbalances also cause the pH to fluctuate, usually to drop. Nutrients used at different rates create an imbalanced formulation. Avert problems by using pure nutrients and thoroughly flushing the soilless medium with fresh tepid water between nutrient solutions.

Hydroponics gives the means to supply the maximum amount of nutrients a plant needs, but it can

To remove roots and sterilize the growing medium:

1. Manually remove the mat of roots that are entwined near the bottom of the bed, and shake loose any attached growing medium. It may be easier to add more medium than to pick it from between the matted roots
2. Pour growing mediums such as expanded clay and gravel through a screen placed over a large bucket. Most of the roots will stay on the screen.
3. Lay growing medium out on the floor, and train an oscillating fan on it to dry out remaining roots.



Here is one of the many popular brands of liquid hydroponic fertilizer.

also starve them to death or rapidly over-fertilize them. Remember, hydroponic systems are designed for high performance. If one thing mal-functions, say the electricity goes off, the pump breaks, the drain gets clogged with roots, or there is a rapid fluctuation in the pH, major problems could result in the garden. A mistake could kill or stunt plants so badly that they do not have time to recover before harvest.

Solution Maintenance

Plants use so much water that nutrient solutions need to be replenished regularly. Water is used at a much faster rate than nutrients. Casually "topping off" the reservoir with pH-balanced water will keep the solution relatively balanced for a week or two. Some growers top off the nutrient solution with 500-700 ppm-strength nutrient solution every two to three days. Never let the nutrient solution go for more than four weeks before draining it and adding fresh solution. Smart growers leach the entire system with weak nutrient solution for an hour or more between changing the reservoir. Wipe down the entire system with the solution.

Do not flush with plain water. Flushing with mild (quarter-strength) nutrient solution will actually remove more excess fertilizer than plain water.

Check EC of reservoir, growing medium, and runoff nutrient solution at the same time every day.

Use an electronic EC pen to monitor the level of dissolved solids in the solution. Occasionally you will need to add more fertilizer concentrate to

maintain the EC level in the reservoir during the "topping off" times. Keep the reservoir full at all times. The smaller the reservoir, the more rapid the depletion and the more critical it is to keep it full. Smaller reservoirs should be refilled daily.

Nutrient Solution Composition

The chart at left is a guideline of satisfactory nutrient limits expressed in ppm. Do not deviate too far from these ranges to avert nutrient deficiencies and excesses.

Hydro-Organic

Hydro-Organic is a means of growing cannabis in an inert soilless medium and feeding with a soluble organic nutrient solution. Organic fertilizers are most often defined as containing substances with a carbon molecule or a natural unaltered substance such as ground-up rocks.

Dedicated growers spend the time and trouble it takes to grow hydro-organically, because the natural nutrients bring out a sweet organic taste in buds. Indoor and outdoor crops grown in less than 90 days do not have time to wait for organic nutrients to be broken down. Organic nutrients must be soluble and readily available for short cannabis crops to benefit.

An exact balance of organic nutrients can be achieved with constant experimentation and attention to details. Even when you buy ready-mixed commercial fertilizers like BioCanna, Earth Juice, or Fox Farm, you will need to try different feeding amounts and schedules to get the exact combination to grow top-quality bud.

Taking an accurate EC reading or mixing the exact amount of a specific nutrient is very difficult in organic hydroponics. Chemical fertilizers are easy to measure out and apply. It is easy to give plants the specific amount of fertilizer they need in each stage of growth.

Organic nutrients have a complex structure, and measuring content is difficult. Organics are difficult to keep stable, too. Some manufacturers, including BioCanna, Earth Juice, and Fox Farm, have managed to stabilize their fertilizers. When buying organic nutrients, always buy from the same sup-

ELEMENT	Limits	Average
Nitrogen	150-1000	250
Calcium	100-500	200
Magnesium	50-100	75
Phosphorus	50-100	80
Potassium	100-400	300
Sulfur	200-1000	400
Copper	0.1-0.5	0.05
Boron	0.5-5.0	1.0
Iron	2.0-10	5.0
Manganese	0.5-5.0	2.0
Molybdenum	0.01-0.05	0.02
Zinc	0.5-1.0	0.5

plier, and find out as much as possible about the source from which the fertilizers were derived.

Combine premixed soluble organic fertilizers with other organic ingredients to make your own blend. Growers experiment to find the perfect mix for their system and the varieties they are growing. Adding too much fertilizer can toxify soil and bind up nutrients, making them unavailable. Foliage and roots burn when the condition is severe.

Soluble organic fertilizers are fairly easy to flush from the growing medium. Like chemical fertilizers, organic fertilizers build to toxic levels easily. Look for the same symptoms as in soil-burned leaf tips, discolored misshapen leaves, brittle leaves, etc. Organic nutrients require heavier flushing. Rinse medium with three gallons of water for every gallon of medium. Some growers flush with plain water the last two weeks of flowering to get all fertilizer taste out of buds.

Mix seaweed with macronutrients and secondary nutrients to make a hydro-organic fertilizer. The amount of primary and secondary nutrients is not as important as the menagerie of trace elements that are in an available form in the seaweed. Major nutrients can be applied via soluble fish emulsion for nitrogen; phosphorous and potassium are supplied by bat guano, bone meal, and manures. More and more organic growers are adding growth stimulators such as humic acid, trichoderma bacteria, and hormones.

Reservoirs

Nutrient solution reservoirs should be as big as possible and have a lid to lessen evaporation. Gardens use from 5-25 percent of the nutrient solution every day. A big volume of nutrient solution will minimize nutrient imbalances. When the water is used, the concentration of elements in the solution increases; there is less water in the solution and nearly the same amount of nutrients. Add water as soon as the solution level drops. The reservoir should contain at least 25 percent more nutrient solution than it takes to fill the beds to compensate for daily use and evaporation. The greater the volume of nutrient solution, the more forgiving the system and the easier it is to control. Forgetting to replenish the water supply and/or nutrient solution could result in crop failure.

Check the level of the reservoir daily, and replenish if necessary. A reservoir that loses more than 20 percent of its volume daily can be topped off with pure or low (500 ppm) EC water. Sophisticated systems have a float valve that controls the level of water in the reservoir.

If your reservoir does not have graduated measurements to denote liquid volume, use an indelible marker to make a full line and the number of gallons or liters contained at that point on the inside of the reservoir tank. Use this volume measure when mixing nutrients.

Soluble Salts Range Chart

Electrical conductivity (EC) as milliSiemen (mS) and total dissolved solids (TDS) as parts per million (ppm)

RANGE DESIRABLE (but potential for concern) EC as mS	PERMISSIBLE	PROBABLE SALT DAMAGE
0.75 to 2.0	2.0 to 3.0	3.0 and up TDS as ppm
500 to 1300	1300 to 2000	2000 and up

For nutrient solutions' determinations, one (1) mS (milliSiemen) or one mMho/cm² is equivalent to approximately 650 ppm total dissolved solids.



This innovative reservoir was made by lining a large galvanized pipe with heavy-duty plastic.



A float valve will turn water on to fill the reservoir when the level drops.



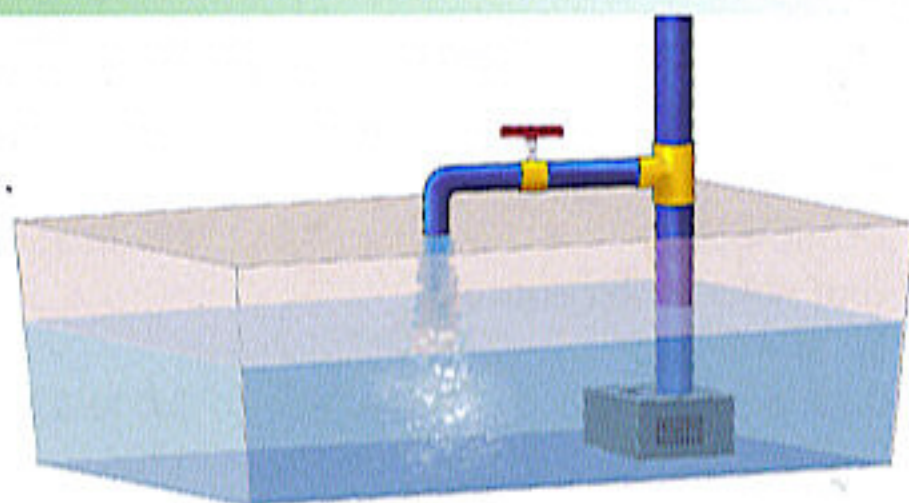
A two-part nutrient solution is mixed before application. Each reservoir holds one part of the solution.



Cover reservoirs to avoid extra evaporation, and to prevent contamination and algae growth.



Nutrient solution is aerated by falling through the air when it returns to the reservoir.



Attach a recirculating pipe with an on/off valve to the pump outlet pipe. This is a convenient and easy-to-control method of aerating the nutrient solution.

The pump should be set up to lift the solution out of the reservoir. Set reservoirs high enough so spent nutrient solution can be siphoned or gravity-flow into a drain or the outdoor garden.

Reservoir Temperature

The temperature of the nutrient solution should stay between 60-75°F (15-24°C). However, nutrient solution will hold much more oxygen at 60°F (15°C) than it will at 75°F (24°C). Never let the nutrient solution temperature climb above 85°F (29°C). Above 85°F (29°C), the solution holds little oxygen. Roots are easily damaged by temperatures 85°F (29°C) and above. Heat-damaged roots are very susceptible to rot, wilts, and fungus gnat attacks.

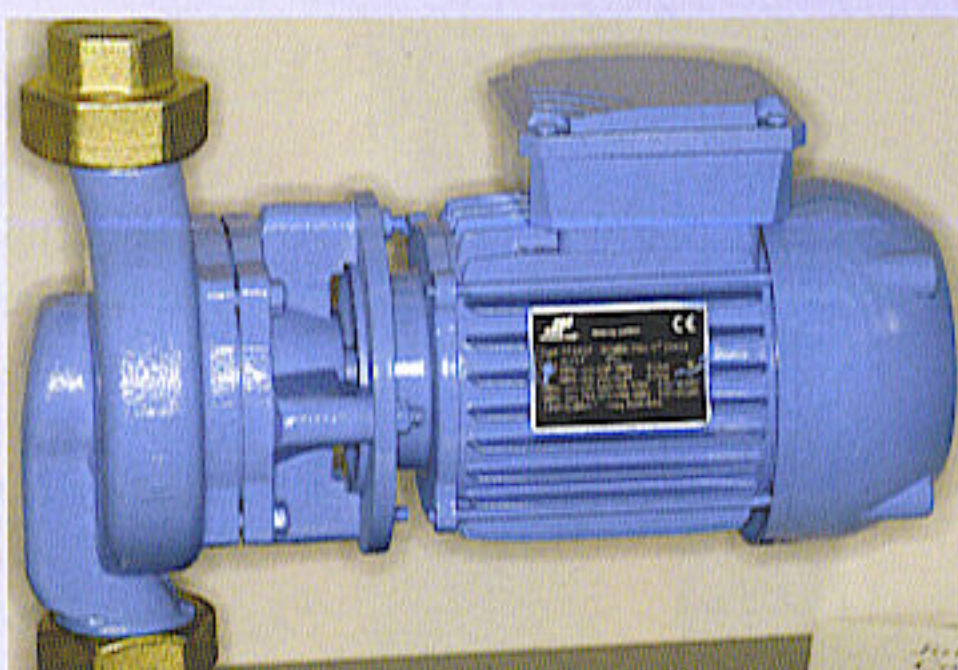
To save energy and money, heat the nutrient solution instead of the air in a room. Heat the nutrient solution with a submersible aquarium heater or grounded propagation heating cables. The heaters might take a day or longer to raise the temperature of a large volume of solution. Do not leave heaters in an empty reservoir. They will soon overheat and burn out. Aquarium heaters seldom have ground wires, a seemingly obvious oversight. But I have yet to learn of an electrocution by aquarium heater. Avoid submersible heaters that give off harmful residues.

When air is cooler than water, moisture rapidly evaporates into the air; the greater the temperature differential, the higher the relative humidity. Maintaining the nutrient solution temperature around 60°F (15°C) will help control transpiration and humidity. It will also promote the uptake of nutrients.

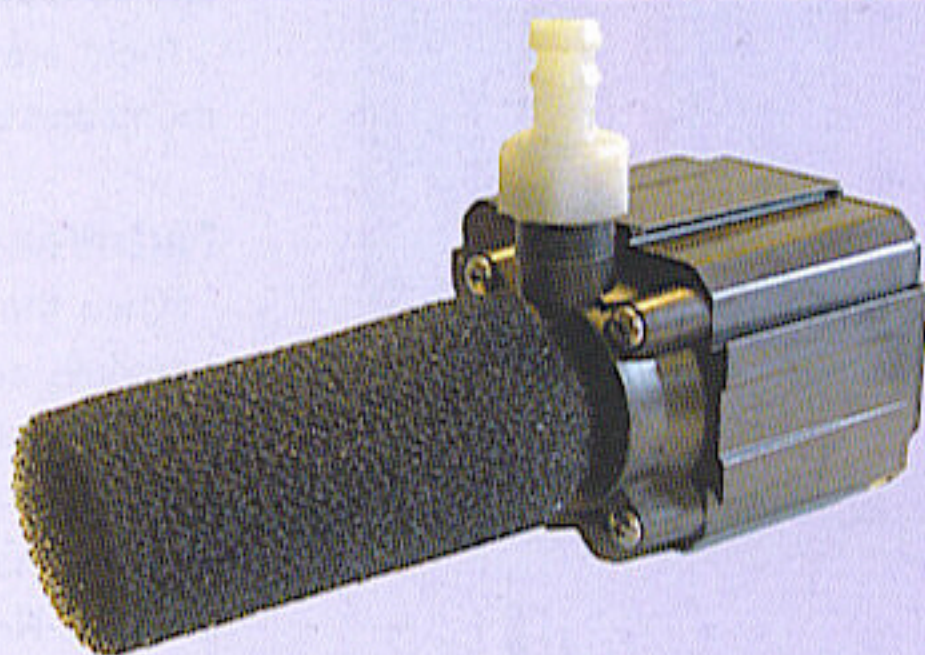
An air pump submerged in the reservoir not only aerates the solution, it will help level out the temperature differential between ambient air and reservoir.

Irrigation

Irrigation is a science unto itself. Irrigation cycles depend on plant size, climate conditions, and the type of medium used. Large, round, smooth particles of substrate drain rapidly and need to be irrigated more often—four to twelve times daily for



Large non-submersible pumps quickly and efficiently move considerable volumes of nutrient solution.

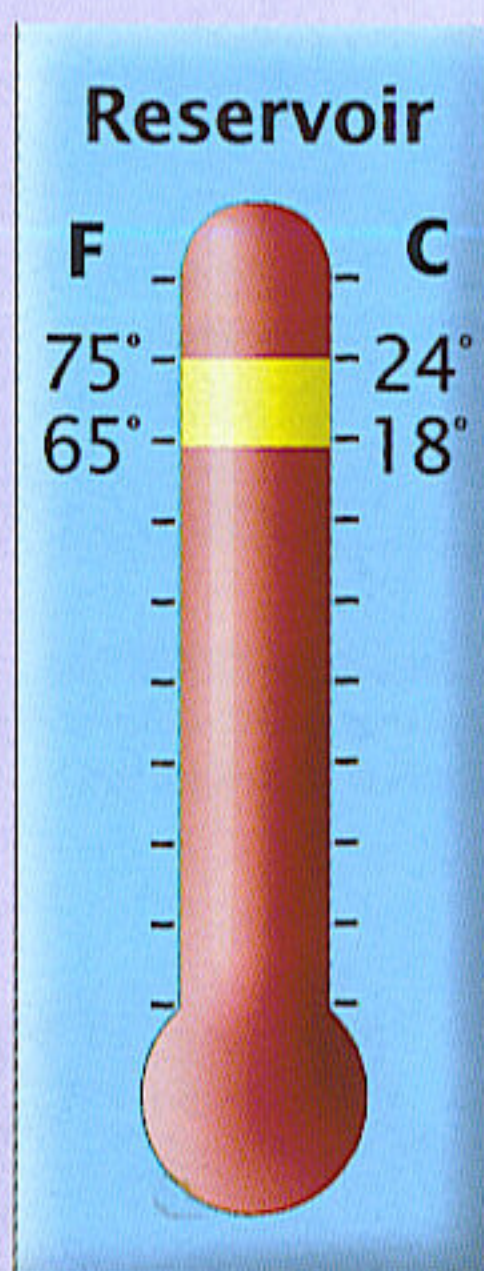


A removable foam filter on the intake of this submersible pump removes particles that could clog the impeller and feeder tubes.



A handle and stand on this pump make it easy to move and mount into a fixed position.

five- to thirty-minute cycles. Fibrous mediums with irregular surfaces, such as vermiculite, drain slowly and require less frequent watering, often just once per day. The water comes to within one-half inch (1.5 cm) of the top of the gravel and should completely drain out of the medium after each water-



Reservoir temperature range



Use an aquarium heater to warm cold reservoirs. Do not let the reservoir dry out when the heater is on or it will burn out.

ing. Top-feed systems cycle for about five minutes or longer and should be irrigated at least three times daily. Often growers cycle the nutrient solution 24 hours a day, especially when growing in fast-draining expanded clay or similar mediums.

In fast-draining mediums, overhead irrigation is continual. Drip irrigation in coco coir is four or five times daily. Flood and drain irrigation cycles are five to ten times daily.

During and soon after irrigation, the nutrient content of the bed and the reservoir are the same concentration. As time passes between irrigations, the EC and the pH gradually change. If enough time passes between irrigations, the nutrient concentration might change so much that the plant is not able to draw it in.

There are many variations on how often to water. Experimentation will tell you more than anything else.

Nutrient Disorders

When the hydroponic garden is on a regular maintenance schedule, and the grower knows the crop well, nutrient problems are usually averted. If nutrient deficiency or excess affects more than a few plants, check the irrigation fittings to ensure nutrient-challenged plants are receiving a full dose of nutrient solution. Next, check the substrate around affected plants to ensure nutrient solution is penetrating entire medium and all roots are wet. Check the root zone to ensure roots have not plugged drainage conduits and are not standing in stagnant solution.

Change the nutrient solution if there is a good flow of nutrient solution through the root zone, but plants still appear sickly. Make sure the pH of the water is within the acceptable 5.5-6.5 range before adding new nutrients.

If changing solution does not solve the problem, changing to a new brand of fertilizer may do the trick. Check out the color drawings of specific nutrient deficiencies and excesses in Chapter Eleven to determine the exact problem, and add 10 to 20 percent more of the deficient nutrient in a chelated form until the disorder has disappeared. Leach growing medium with dilute nutrient solution to solve simple overdose nutrient problems.

Hydroponic gardens have no soil to buffer the uptake of nutrients. This causes nutrient disorders to manifest as discolored foliage, slow growth, spotting, etc., at a rapid rate. Novice gardeners must learn how to recognize nutrient problems in their early stages to avoid serious problems that cost valuable time for plants to recoup. Treatment for a nutrient deficiency or excess must be rapid and certain. But once treated, plants

take several days to respond to the remedy. For a fast fix, foliar feed plants. See "Foliar Feeding" in Chapter Eleven.

Nutrient deficiency or excess diagnosis becomes difficult when two or more elements are deficient or in excess at the same time. Symptoms might not point directly at the cause. Solve mind-bending unknown nutrient deficiency syndromes by changing the nutrient solution. Plants do not always need an accurate diagnosis when the nutrient solution is changed.

Over-fertilization, once diagnosed, is easy to remedy. Drain the nutrient solution. Flush the system at least twice with fresh dilute (5-10 percent) nutrient solution to remove any lingering sediment and salt buildup in the reservoir. Replace with properly mixed solution.

Nutrient disorders most often affect a strain at the same time when it is receiving the same nutrient solution. Different varieties often react differently to the same nutrient solution. Do not confuse other problems—wind burn, lack of light, temperature stress, fungi and pest damage—with nutrient deficiencies. Such problems usually appear on individual plants that are most affected. For example, foliage next to a heat vent might show signs of heat scorch, while the rest of the garden looks healthy. Or a plant on the edge of the garden would be small and leggy because it receives less light.



Here are some guidelines:

1. Water when plants are half-empty of water; weigh pots to tell.
2. Water soil gardens when soil is dry one-half inch (1.5 cm) below the surface.
3. Water soil gardens with a mild nutrient solution and let 10-20 percent drain off at each watering.
4. Do not let soil dry out to the point that plants wilt.



A handle and stand on this pump make it easy to move and mount into a fixed position.



Top feed buckets.



Ebb and flow tables can be the length of a greenhouse. Long tables take a long time to flood and require a huge reservoir of nutrient solution.



Big beautiful buds grow super dense on tables.

Chapter THIRTEEN

AIR



A carbon filter and ozone exchange box dominate the landscape in this Dutch grow room.

Introduction

Fresh air is essential in all gardens. Indoors, it could be the difference between success and failure. Outdoor air is abundant and packed with carbon dioxide (CO₂) necessary for plant



Monitor temperature and humidity regularly. The 86°F (33°C) 34 percent relative humidity conditions make plants use more water and less fertilizer. Adjust irrigation schedule to meet needs.



Smoke is immediately sucked out of the room when using this in-line fan. The fan demonstration took place at the 2000 CannaBusiness trade show in Germany.

life. For example, the level of CO₂ in the air over a field of rapidly growing cannabis could be only a third of normal on a very still day. Wind blows in fresh CO₂-rich air. Rain washes air and plants of dust and pollutants. The outdoor environment is often harsh and unpredictable, but there is always fresh air. Indoor gardens must be meticulously controlled to replicate the outdoor atmosphere.

Carbon dioxide and oxygen provide basic building blocks for plant life. Oxygen is used for respiration—burning carbohydrates and other foods to provide energy. Carbon dioxide must be present during photosynthesis. Without CO₂, a plant will die. Carbon dioxide combines light energy with water to produce sugars. These sugars fuel the growth and metabolism of the plant. With reduced levels of CO₂, growth slows to a crawl. Except during darkness, a plant releases more oxygen than is used and uses much more carbon dioxide than it releases.

Roots use air, too. Oxygen must be present along with water and nutrients for the roots to be able to absorb nutrients. Compacted, water-saturated soil leaves roots little or no air, and nutrient uptake stalls.

Air Movement

Air ventilation and circulation are essential to a healthy indoor harvest. Indoors, fresh air is one of the most overlooked factors contributing to a

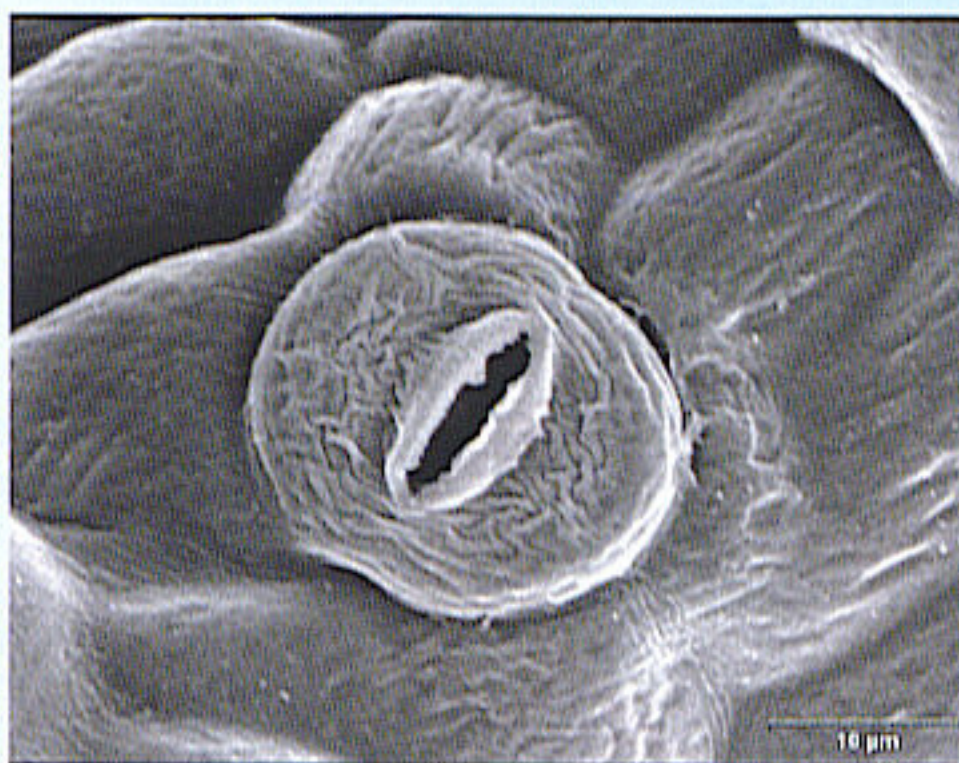


At least one good circulation fan and an extraction fan are necessary in grow rooms. The extraction fan in this grow room is attached to a carbon filter.

healthy garden and a bountiful harvest. Fresh air is the least expensive essential component required to produce a bumper crop. Experienced growers understand the importance of fresh air and take the time to set up an adequate ventilation system. Three factors affect air movement: stomata, ventilation, and circulation.

Stomata

Stomata are microscopic pores on leaf undersides that are similar to an animal's nostrils. Animals regulate the amount of oxygen inhaled and carbon dioxide and other elements exhaled through the nostrils via the lungs. In cannabis, oxygen and carbon dioxide flows are regulated by the stomata. The larger the plant, the more stomata it has to take in carbon dioxide and release oxygen. The greater the volume of plants, the more fresh CO₂-rich air they will need to grow quickly. Dirty, clogged stomata do not work properly and restrict airflow. Stomata are easily clogged by dirt from polluted air and sprays that leave filmy residues. Keep foliage clean. To avoid clogging stomata, spray foliage with tepid water a day or two after spraying with pesticides, fungicides or nutrient solution.

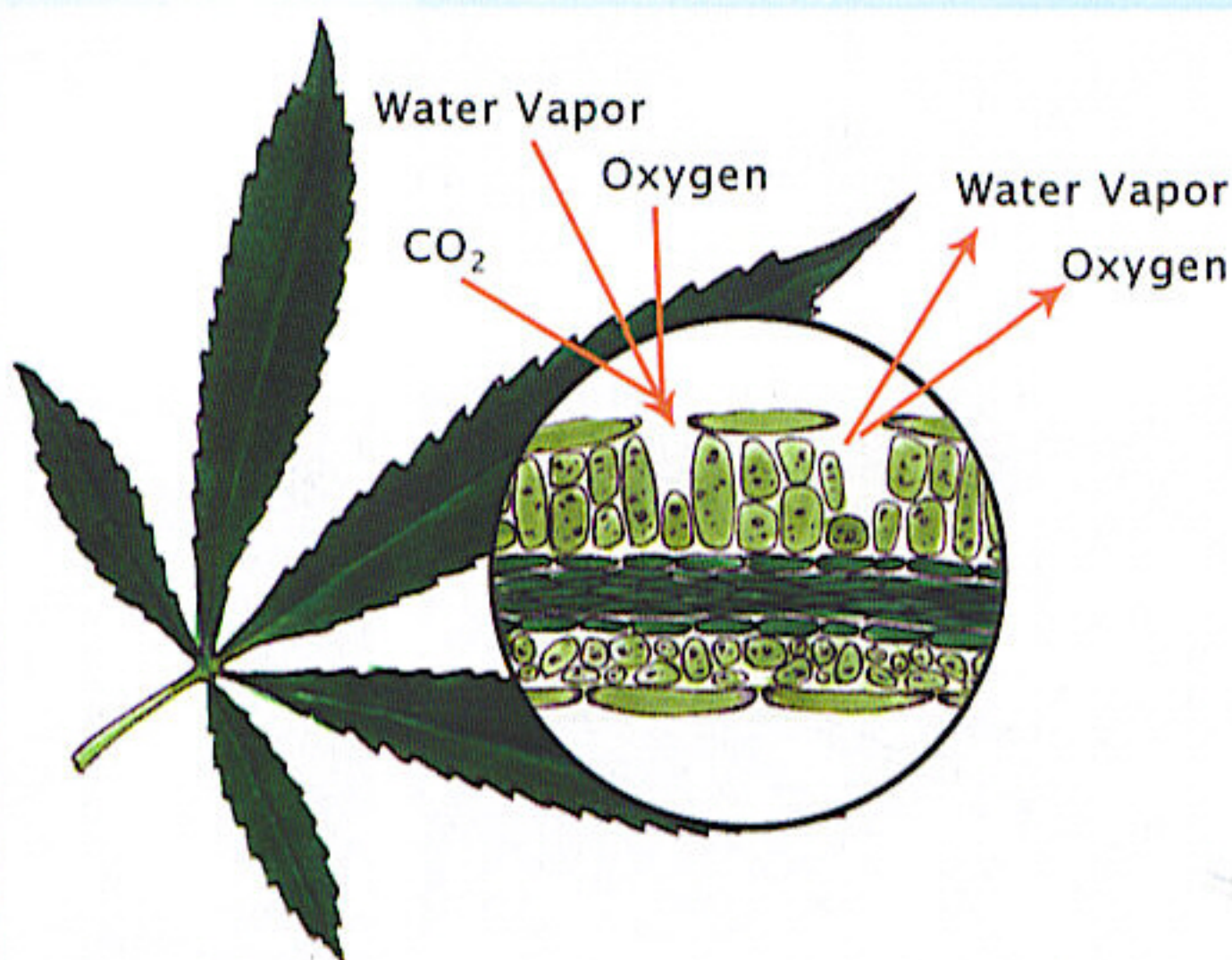


This photo of a half-opened stomata, the mouth-like opening on leaf underside, was magnified 2500 times.

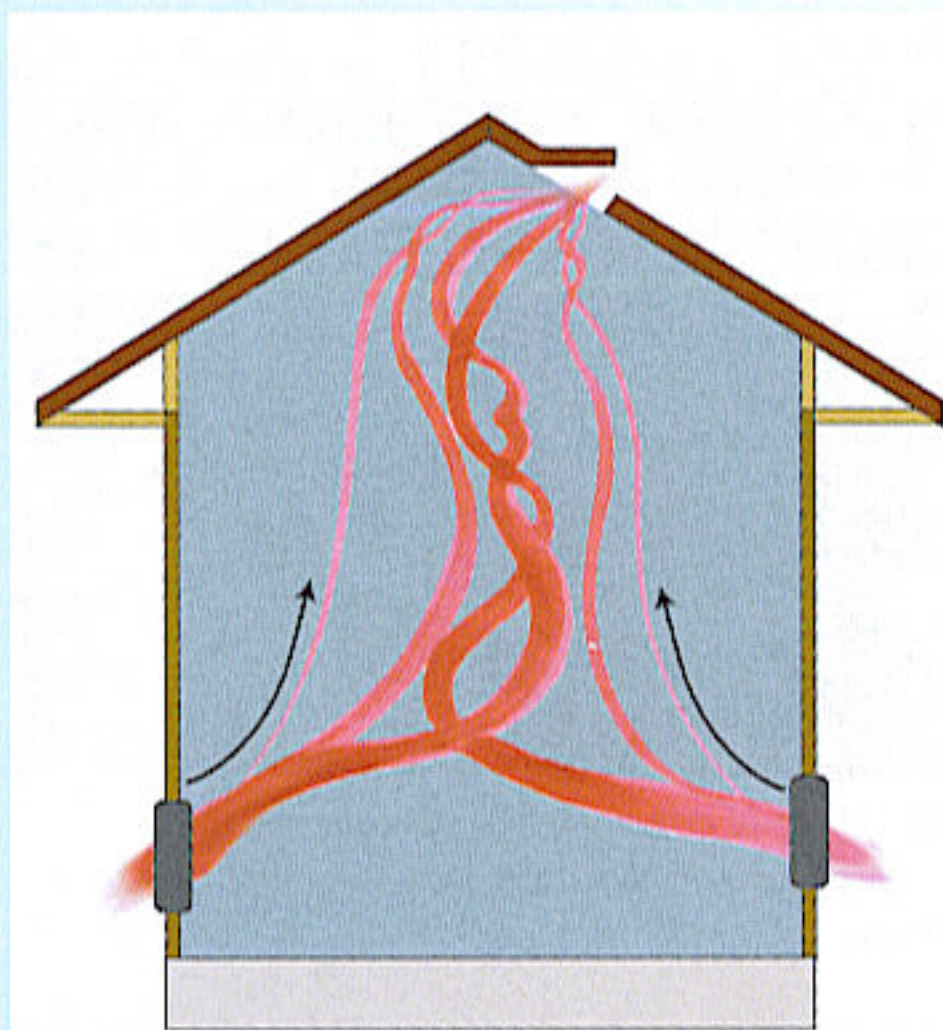
opening a door or window and/or installing an oscillating circulation fan. Air circulation also helps prevent harmful pest and fungus attacks. Omnipresent mold spores do not land and grow as readily when air is stirred by a fan. Insects and spider mites find it difficult to live in an environment that is constantly bombarded by air currents.

Circulation

Plants use all CO₂ around the leaf within a few minutes. When no new CO₂-rich air replaces the used CO₂-depleted air, a dead air zone forms around the leaf. This stifles stomata and virtually stops growth. If it is not actively moved, the air around leaves stratifies. Warm air stays near the ceiling, and cool air settles near the floor. Air circulation breaks up these air masses, mixing them together. Avoid these would-be problems by



Microscopic stomata located on leaf undersides must remain clean and un-stifled by humidity to promote rapid growth.



Hot air flows upward naturally. Always design grow rooms and greenhouses to take advantage of this principle.



Floor-mounted oscillating fans stir the air in this room 24 hours a day.



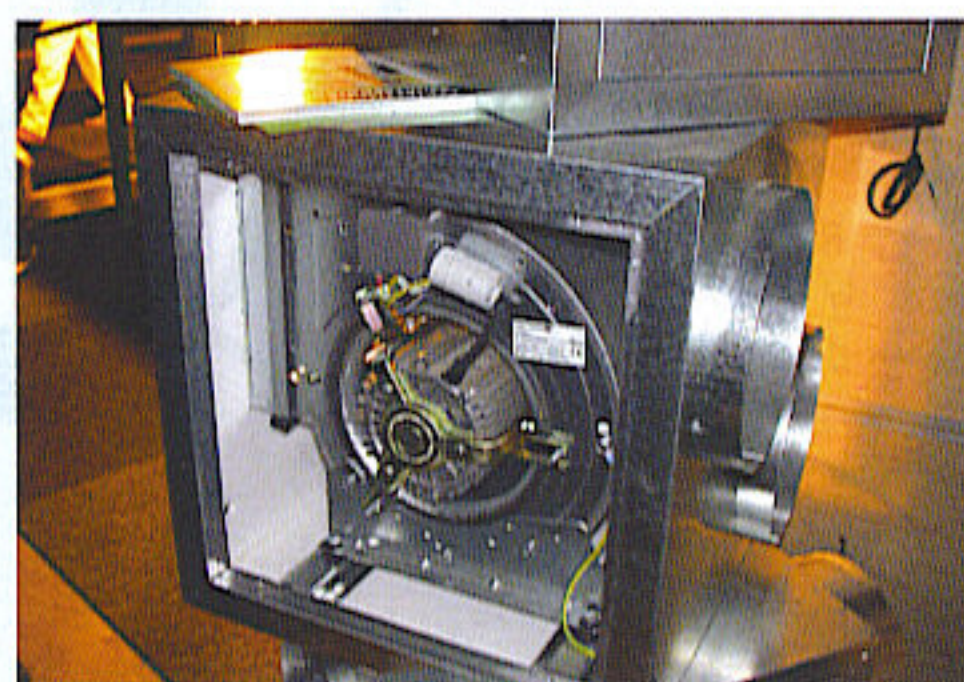
Place circulation fans far enough away from plants to prevent too much airflow on any one portion of the garden.



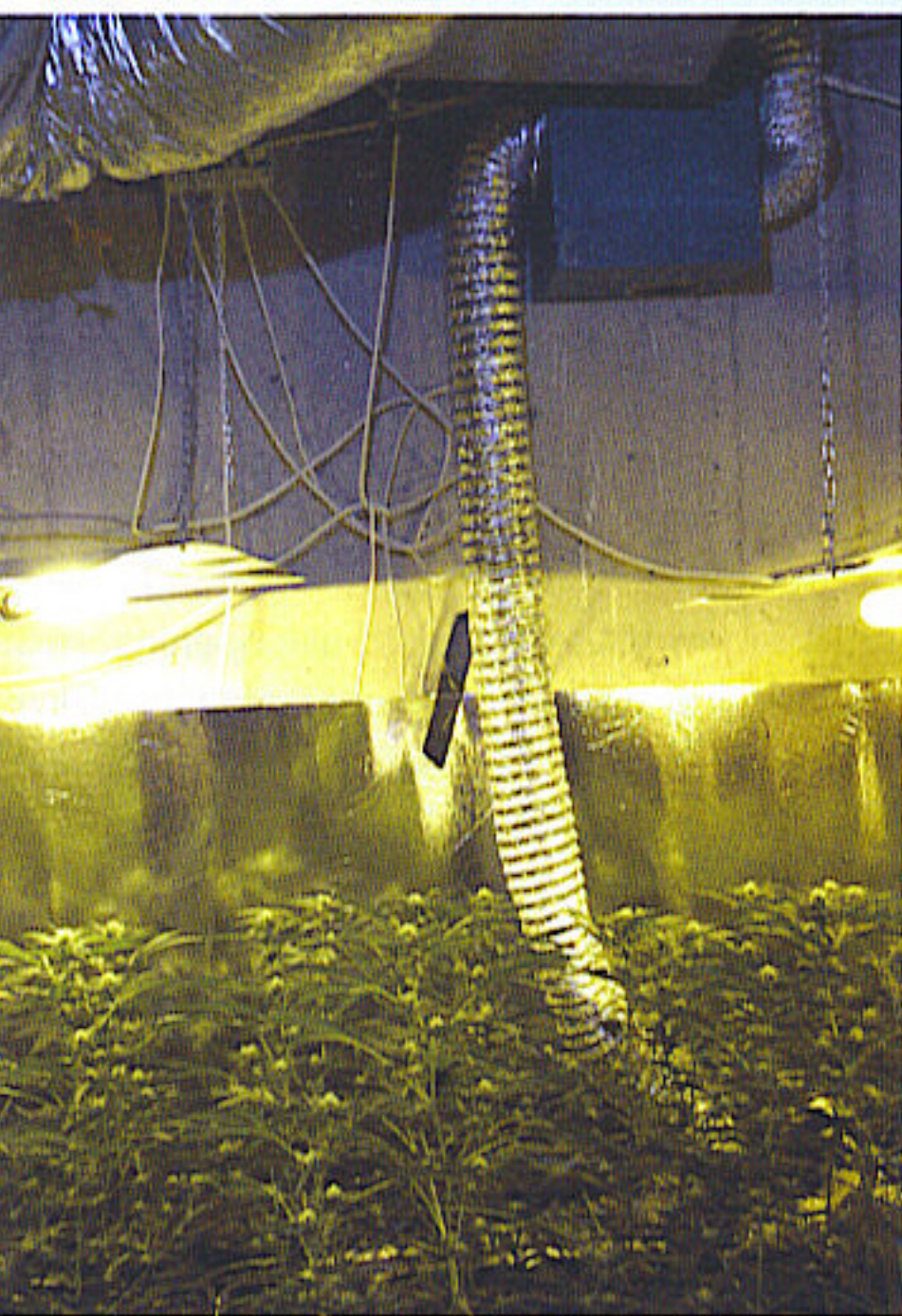
This garden has several circulation fans to move air between dense, resinous buds.



CO₂ around leaves is used quickly and must be replaced every few minutes.



Here is an example of a heavy-duty extractor fan from a Dutch grow room.



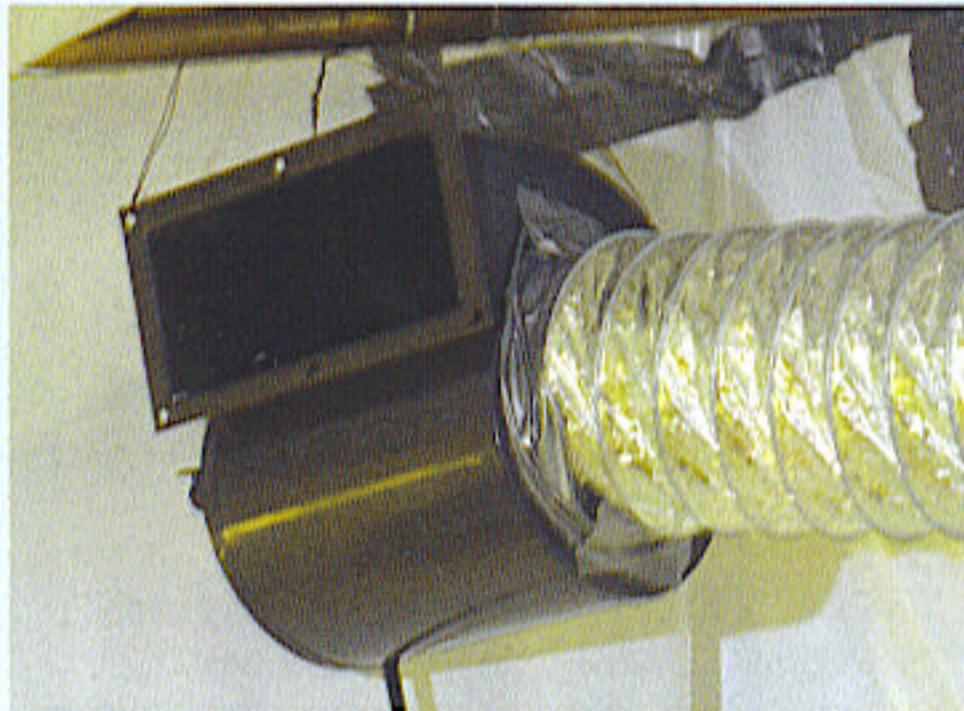
A booster fan in the gray box pushes intake air down the duct to the bottom of the garden.



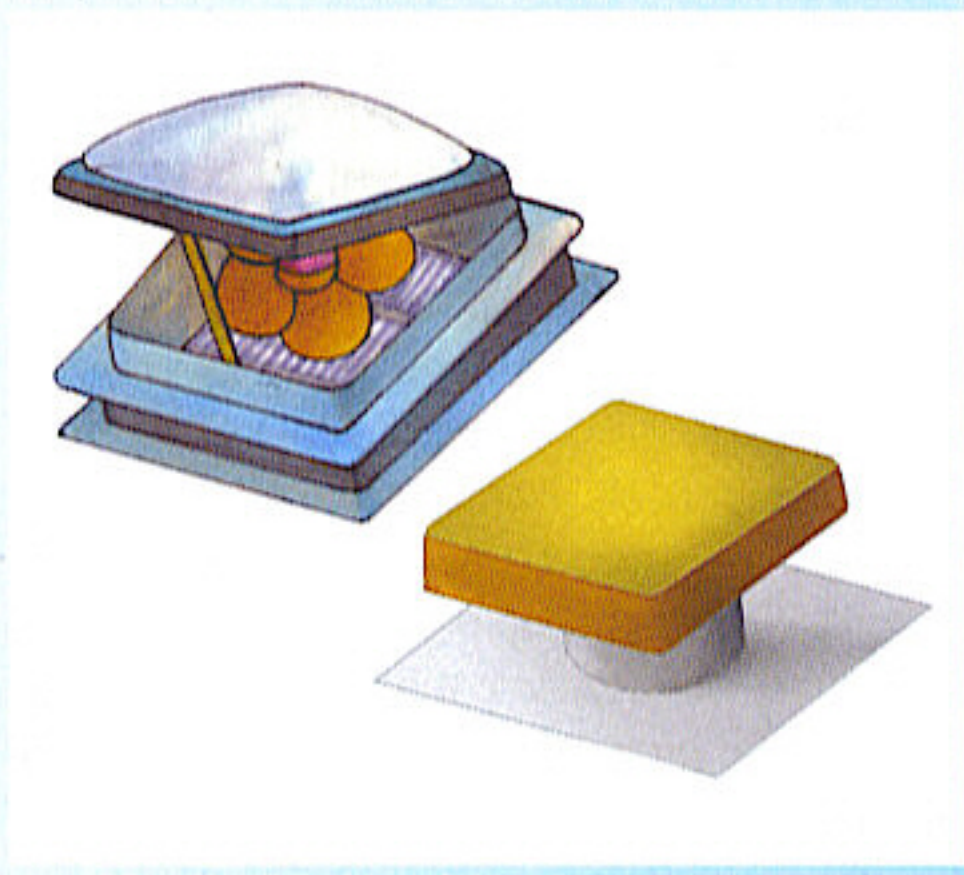
Avoid long, unnecessary ducting such as shown above. Keep ducting as short as possible.



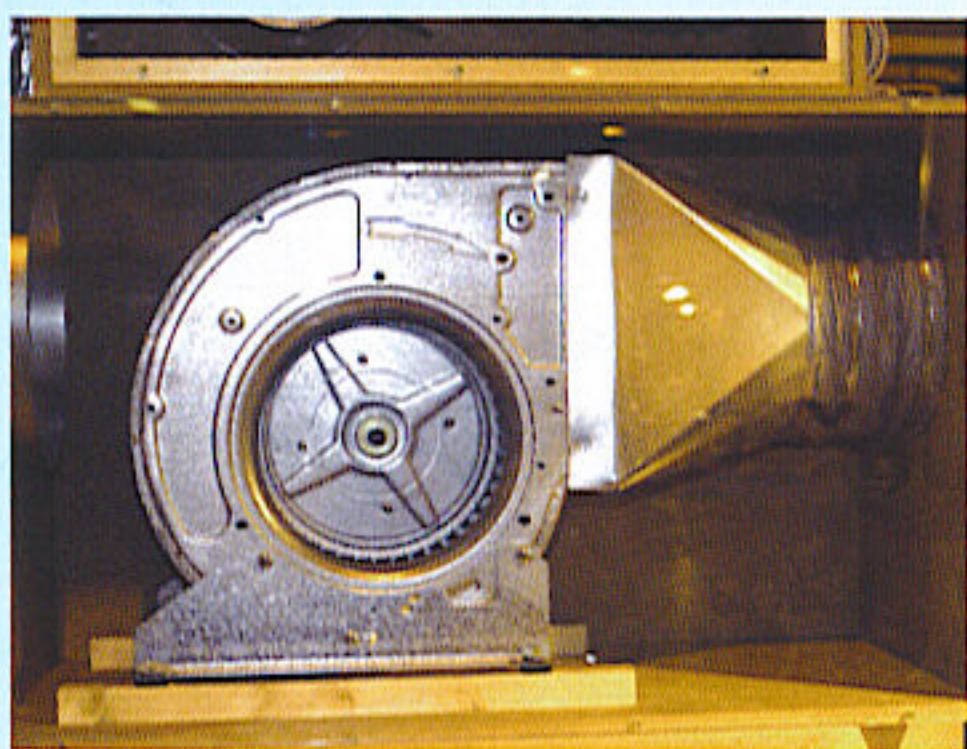
Ballasts are kept in the box which contains the extra heat. Separate ducting carries out the hot air.



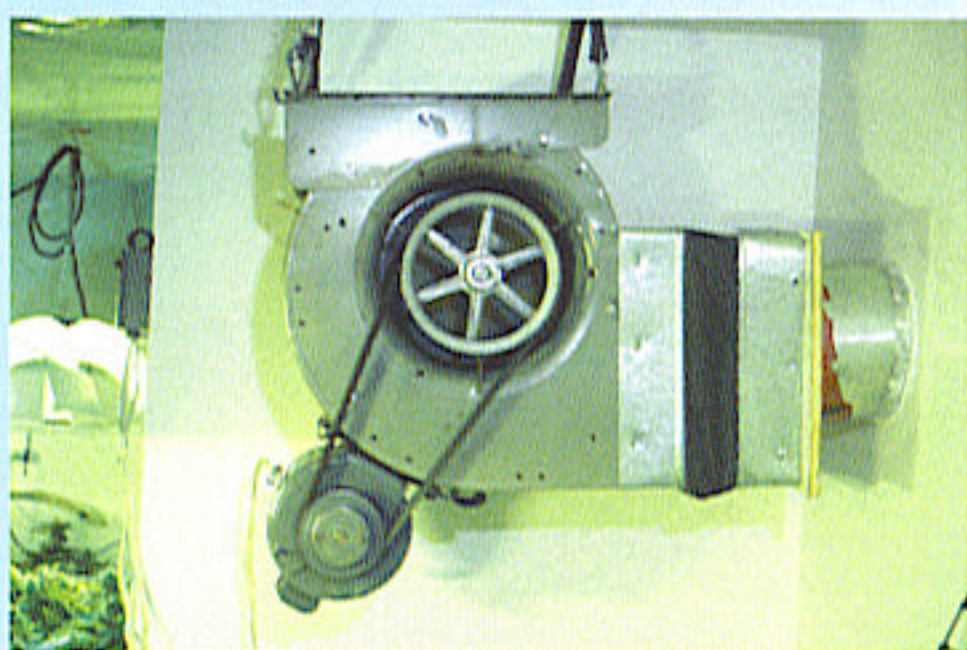
This blower is at the end of intake air ducting. The main fan is at the other end.



Roof fans and vents make grow room ventilation easy and inconspicuous.



Squirrel cage blower moves a lot of air, but it is noisy! This blower has been necked down to force more air through the ducting.



This fan is suspended by bungee cords to shunt noisy vibrations. Always keep your fans well lubricated so they run smoothly and quietly.

Ventilation

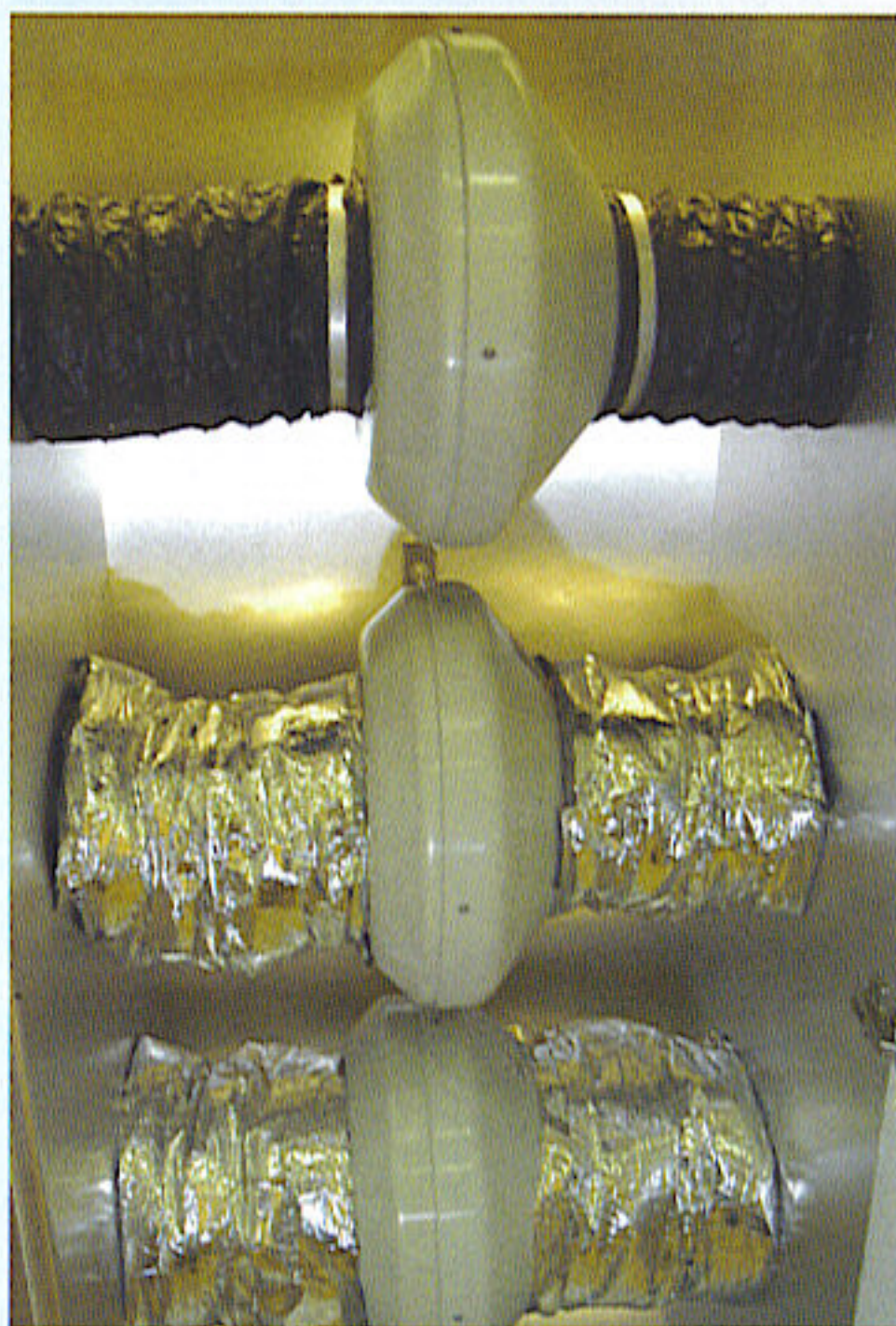
Fresh air is easy to obtain and inexpensive to maintain—it is as simple as hooking up and placing the proper-sized exhaust fan in the most efficient location. An intake vent may be necessary to create a flow of fresh air in the room.

A 10-foot square (0.92 m²) garden will use from 10 to 50 gallons (38 to 190L) or more of water every week. Plants transpire (similar to evaporation) most of this water into the air. Every day and night, rapidly growing plants transpire more moisture into the air. If this moisture is left in the grow room, humidity increases to 100 percent, which stifles stomata and causes growth to screech to a halt. It also opens the door for pest and disease attacks. Replace moist air with fresh, dry air, and transpiration increas-

es, stomata function properly, and growth rebounds. A vent fan that extracts air from the grow room is the perfect solution to remove this humid, stale air. Fresh air flows in through an intake vent or with the help of an intake fan.

Ventilation is as important as water, light, heat, and fertilizer. In many cases, fresh air is even more important. Greenhouses use large ventilation fans. Grow rooms are very similar to greenhouses and should follow their example. Most grow rooms have an easy-to-use opening, such as a window in which to mount a fan, but security or room location may render it unusable. If no vent opening is available, one will have to be created.

All grow rooms require ventilation. This system could be as simple as an open door or window that supplies and circulates fresh air throughout the room, but open doors and windows can be inconvenient and problematic. Most growers



For indoor rooms, in-line fans are one of growers' favorites. These fans are quiet and efficiently move large volumes of air.

elect to install a vent fan. Some growers need to install an entire ventilation system including ductwork and several fans.

A vent fan *pulls* air out of a room four times more efficiently than a fan is able to push it out. Vent fans are rated by the amount of air, measured in cubic feet per minute (CFM) or (square meters per hour [m^3/h]) they can move. The fan should be able to replace the air volume (length $\times$ width $\times$ height = total volume in cubic feet) of the grow room in less than 5 minutes. Once evacuated, new air is immediately drawn in through an intake vent or with the help of an intake fan. (Covering the intake vent with fine mesh silkscreen will help exclude pests.) An intake fan might be necessary to bring an adequate volume of fresh air into the room quickly. Some rooms have so many little cracks for air to drift in that they do not need an intake vent.

Do not set up a circulation fan in the room and expect it to vent the area by pushing air out a distant vent. The circulation fan must be very large to adequately increase air pressure and push enough air out a vent to create an

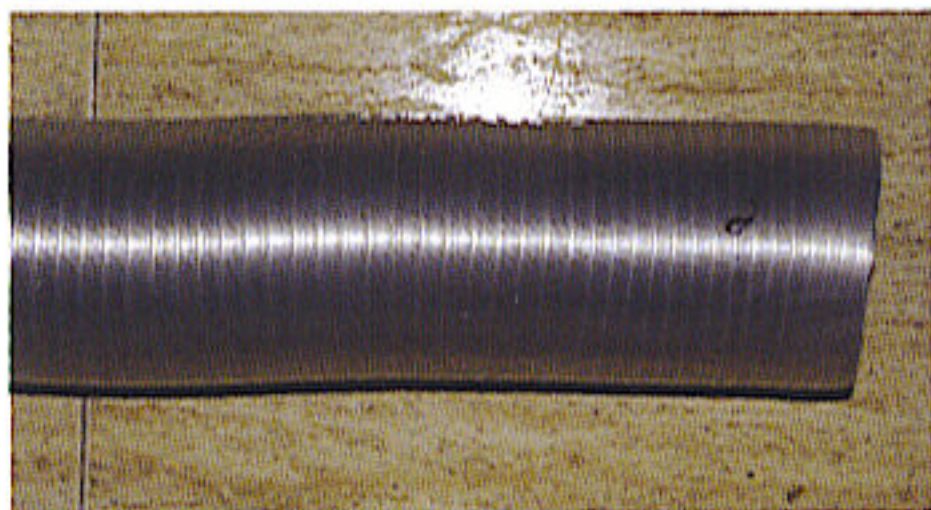
exchange of air. A vent fan, on the other hand, is able to change the pressure and exchange the air quickly and efficiently.

Squirrel cage blowers are efficient at moving air but are very loud. Blowers with a balanced, well-oiled wheel run most quietly. Felt or rubber grommets below each foot of the fan will reduce noise caused by vibrations. Run motor at a low RPM to lessen noise.

In-line fans are designed to fit into a duct pipe. The propellers are mounted to increase the air-flow quickly, effortlessly, and as quietly as possible. In-line fans are available in quiet, high-quality models that run smoothly.

Propeller or muffin fans with large fan blades expel air through a large opening, and are most efficient and quiet when operated at low RPM. A slow-moving propeller fan on the ceiling of a grow room will quietly and efficiently move the air.

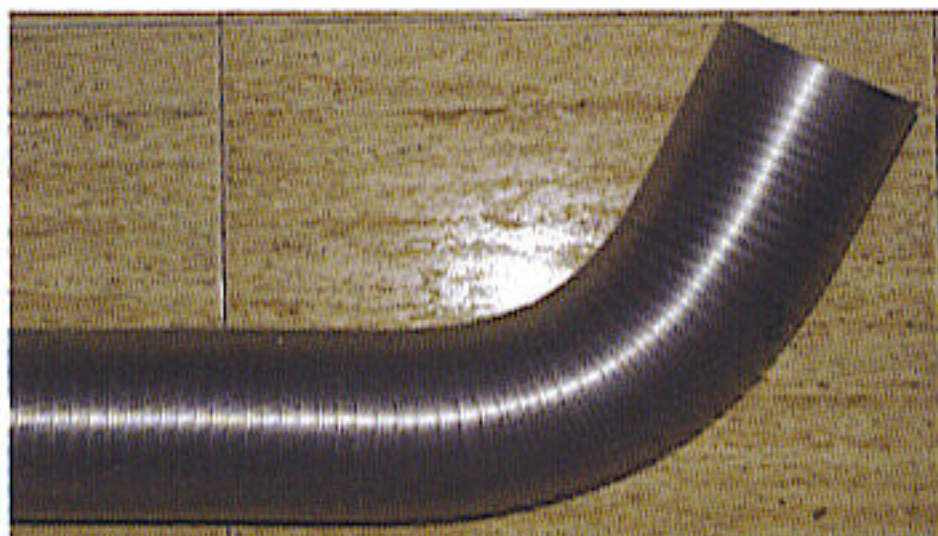
Hot air rises. Adept growers locate air exit vents in the hottest peak of the room for passive, silent air venting. The larger the diameter of the exhaust ducts, the more air that can travel



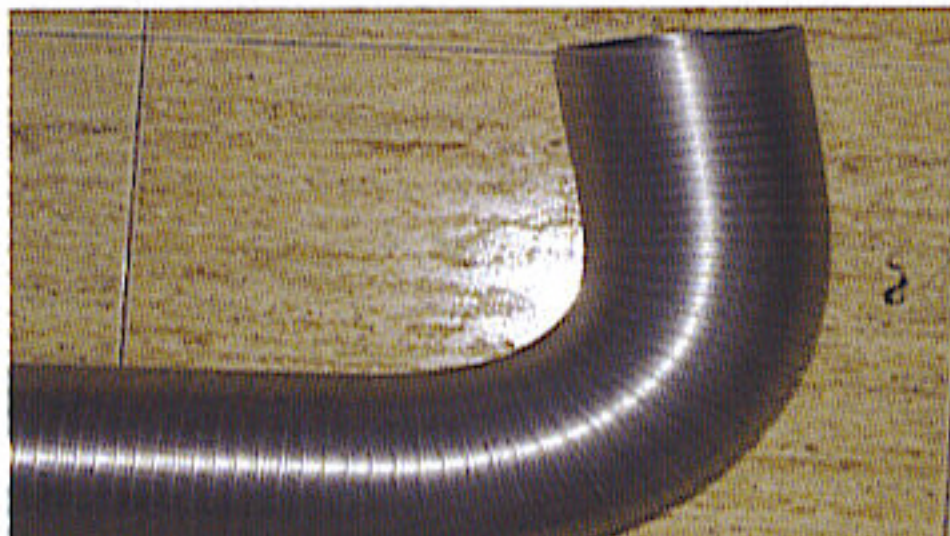
Straight with no bend is the most efficient



Thirty degree curve cuts up to 20 percent of air transmission.



Forty-five degree curve cuts up to 40 percent of air transmission.



Ninety degree curve cuts up to 60 percent of air transmission.



Intake air ducting has holes covered with duct tape. Air flow is directed by removing pieces of tape.



Fresh air in this room is piped in directly where plants need it.



To control the air temperature, hang the thermostat near the canopy of the garden.

through them. By installing a big, slow-moving vent fan in this vent, hot stale air is quietly and efficiently evacuated. A fan running at 50 RPM is quieter than one running at 200 RPM. Smart growers install 12-inch ducting and inline fans.

Most often, the vent fan is attached to ducting that directs air out of the grow room. Flexible ducting is easier to use than rigid ducting. To install, run the duct the shortest possible distance, and keep curves to a minimum. When turned at more than 30°, much of the air that enters a duct will not exit the other end. Keep the ducting straight and short.

Intake Air

Many rooms have enough fresh air coming in via cracks and holes. But other grow rooms are tightly sealed and require fresh air to be ushered in with the help of an intake fan. An intake fan is the same as an exhaust fan, except it blows fresh air into the room. The ratio of 1 to 4 (100 CFM [m^3/h] incoming and 400 CFM [m^3/h] outgoing) should give the room a little negative pressure. Delivering fresh air to plants ensures they will have adequate CO_2 to continue rapid growth. One of the best ways to deliver air directly to plants is to pipe it in via flexible ducting. Ingenious growers cut holes in the intake ducting to direct air where it is needed. The air is dispersed evenly throughout the room.

Always make sure fresh air is neither too hot nor too cold. For example, one friend that lives in a hot, arid climate brings cool fresh air in from under the house, where the air is a few degrees cooler than ambient air.

Security

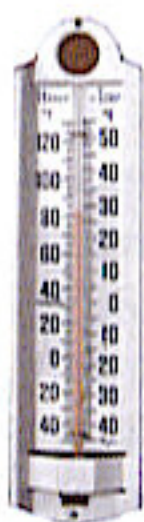
When installing a vent fan, security concerns dictate that no light or odor escape from the exterior vent while allowing ample air release. This can be accomplished in several ways. Baffle or turn the light around a corner to subdue brilliance. Many chimneys in British Columbia, Canada, shoot light out like a spotlight against the low cloud cover. You can walk down city streets where half the chimneys in the neighborhood are beacons of bright light. A 4-inch (10.16 cm) flexible dryer hose will subdue light in smaller grow rooms. Larger 8, 10, and 12-inch (20, 25, 30 cm) heat duct pipe is ideal for moving larger volumes of air.

Place one end of the duct outdoors. It should be high enough, preferably over 12 feet, so the odor disperses above most people's heads. One of the best vents is the chimney. The outlet may be camouflaged by using a dryer hose wall outlet attached to a vent fan. The vent fan is then placed near the ceiling so it vents hot, humid air. Check for light and air leaks. Set up the fan and go outdoors after dark to inspect for light leaks. See below: "Setting Up the Vent Fan" and "Odor."

Greenhouse fans are equipped with louvers (flaps or baffles) to prevent backdrafts. During cold and hot weather, undesirable backdrafts could alter the climate in the room and usher in a menagerie of pests and diseases. Installing a vent fan with louvers eliminates backdrafts, but may present a security risk if it attracts the attention of the wrong crowd.

Temperature

An accurate thermometer is essential to measure temperature in *all* grow rooms. Mercury or liquid thermometers are typically more accurate than spring or dial types, but ecologically unsound. An inexpensive thermometer will collect basic information, but the ideal thermometer is a day-night or maximum/minimum type that measures how low the temperature drops at night and how high it reaches during the day. The maximum and minimum temperatures in a grow room are important for the reasons explained below.



A thermometer that measures in Fahrenheit and Celsius will come in very handy.



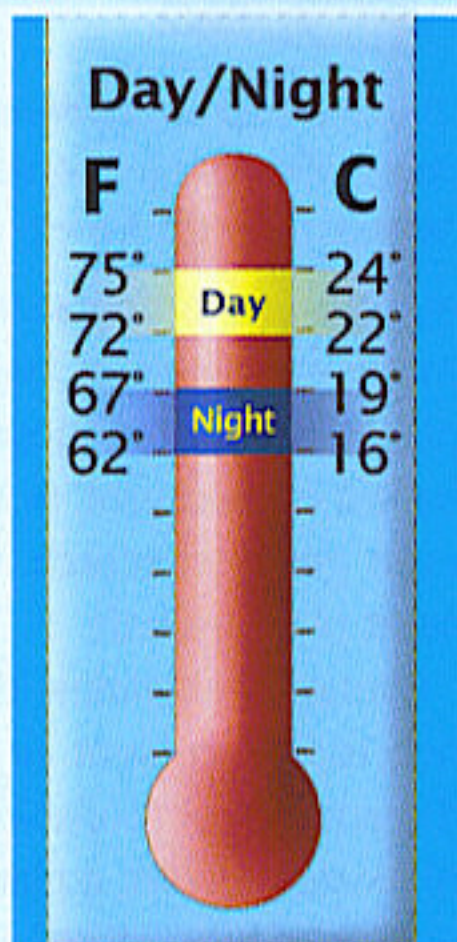
Thermometer Hygrometer



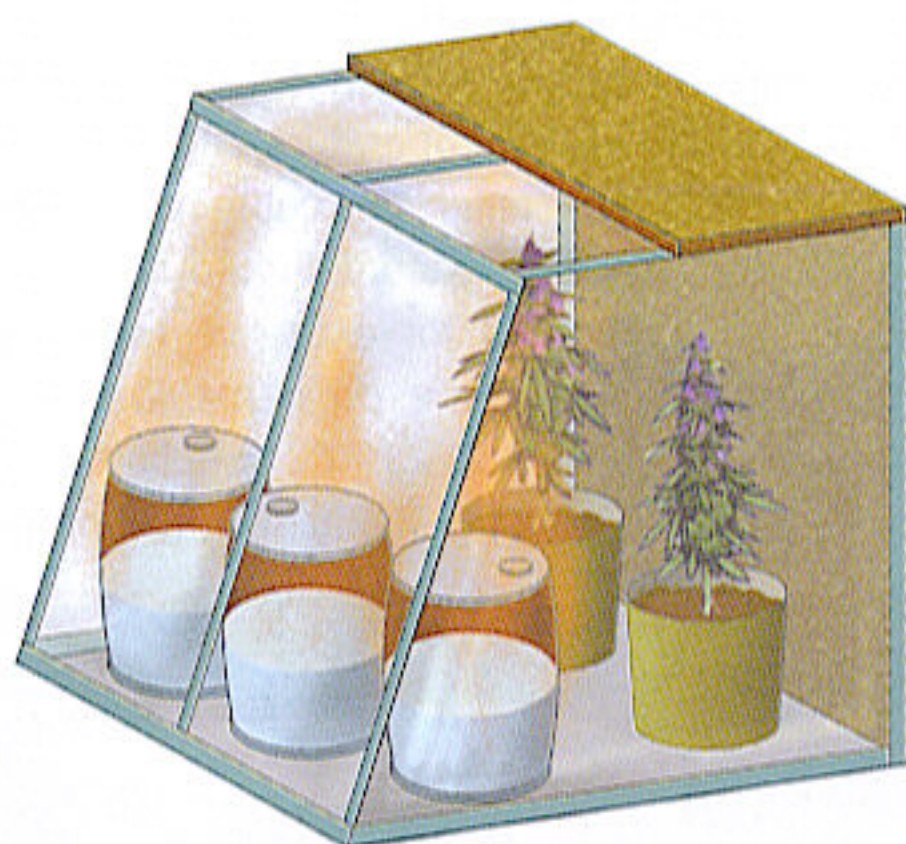
Check the temperature and humidity in several places in the grow room. Lights really heat a room!



This combination thermometer/hygrometer is fairly accurate and easy to mount.



Knowing Celsius and Fahrenheit equivalents makes grow room calculations more precise.



Fill barrels with water and let the sun heat them several days. Water stays warm all night to heat the greenhouse!



This simple humidistat/thermostat controller is just one of many different time/controllers found at www.greenair.com. It is very easy to use and foolproof.

er, constant temperature in the grow room promotes strong, even, healthy growth. Make sure plants are not too close to a heat source, like a ballast or heat vent, or they may dry out, maybe even get heat scorch. Cold intake air will also stunt plant growth.

Cannabis regulates its oxygen uptake in relation to the ambient air temperature rather than the amount of available oxygen. Plants use a lot of oxygen; in fact, a plant cell uses as much oxygen as a human cell. The air must contain at least 20 percent oxygen for plants to thrive. Leaves are not able to make oxygen at night, but roots still need oxygen to grow. A plant's respiration rate approximately doubles every 20°F

(10°C). Root respiration increases as the roots warm up, which is why fresh air is important both day and night.

Temperatures above 85°F (29°C) are not recommended even when using CO₂ enrichment. Under the proper conditions, which are very demanding to maintain, higher temperatures step up metabolic activity and speed growth. The warmer it is, the more water the air is able to hold. This moist air often restrains plant functions and decelerates growth rather than speeding it. Other complications and problems result from excess humidity and moisture condensation when the temperature drops at night.

Heat buildup during warm weather can catch growers off guard and cause serious problems. Ideal grow rooms are located underground, in a basement, taking advantage of the insulating qualities of Mother Earth. With the added heat of the HID and hot, humid weather outdoors, a room can heat up rapidly. More than a few American growers have lost their crops to heat stroke during the Fourth of July weekend, since it is the first big holiday of the summer, and everybody in the city wants to get away to enjoy it. There are always some gardeners that forget or are too paranoid to maintain good ventilation in the grow room while on vacation. Temperatures can easily climb to 100°F (38°C) or more in grow rooms that are poorly insulated and vented. The hotter it is, the more ventilation and water that are necessary.

The cold of winter is the other temperature extreme. Montreal, Quebec, Canada, growers will remember the year of the big ice storm. Electricity went out all over the city and surrounding areas. Water pipes froze, and heating systems failed. Residents were driven from their homes until electricity was restored some days later. Many growers returned to find their beautiful gardens wilted, stricken with the deepest, most disgusting green only a freeze can bring. Broken water pipes, ice everywhere! It is difficult to combat such acts of God, but if possible, always keep the grow room above 40°F (5°C) and definitely above freezing, 32°F (0°C). If the

temperature dips below this mark, the freeze will rupture plant cells, and foliage will die back or, at best, grow slowly. Growth slows when the temperature dips below 50°F (10°C). Stressing plants with cold weather conditions is not recommended; it may yield a proportionately higher THC content, but will reduce plants' overall productivity.

A thermostat measures the temperature, then controls it by turning on or off a device that regulates heating or cooling, keeping the temperature within a predetermined range. A thermostat can be attached to an electric or combustion heater. In fact, many homes are already setup with electric baseboard heat and a thermostat in each room.

A thermostat can be used to control cooling vent fans in all but the coldest grow rooms. When it gets too hot in a room, the thermostat turns on the vent fan, which evacuates the hot stale air. The vent fan remains on until the desired temperature is reached, then the thermostat turns off the fan. A thermostat-controlled vent fan offers adequate temperature and humidity control for many grow rooms. A refrigerated air conditioner can be installed if heat and humidity are a major problem. Just remember, air conditioners draw a lot of electricity. If excessive heat is a problem, but humidity is not a concern, use a swamp cooler. These evaporative coolers are inexpensive to operate and keep rooms cool in arid climates.

Common thermostats include single-stage and two-stage. The single-stage thermostat controls a device that keeps the temperature the same both day and night. A two-stage thermostat is more expensive but can be set to maintain different daytime and nighttime temperatures. This convenience can save money on heating, since room temperature can drop 5-10°F (2-5°C) at night with little effect on growth.

Many new grow room controllers have been developed in the last ten years. These controllers can operate and integrate every appliance in the grow room. More sophisticated controllers integrate the operation of CO₂ equip-



This air conditioner lowers grow room temperature and humidity. The hot radiator is outside, about 10 feet (3 m) away.



A simple electric heater may be necessary to warm the room after lights go out.

ment, vent, and intake fans. Relatively inexpensive computerized controllers are also available for grow rooms. If temperature and humidity regulation are causing cultural problems in the grow room, consider purchasing a controller.

Un-insulated grow rooms or grow rooms that experience significant temperature fluctuations require special consideration and care. Before growing in such a location, make sure it is the only choice. If forced to use a sun-baked attic that cools at night, make sure maximum

insulation is in place to help balance temperature instability. Enclose the room to control heating and cooling.

When CO₂ is enriched to 0.12-0.15 percent (1200–1500 ppm), a temperature of 85°F (29°C) promotes more rapid exchange of gases. Photosynthesis and chlorophyll synthesis are able to take place at a more rapid rate causing plants to grow faster. Remember, this higher temperature increases water, nutrient, and space consumption, so be prepared! Carbon dioxide-enriched plants still need ventilation to remove stale, humid air and promote plant health.

The temperature in the grow room tends to stay the same, top to bottom, when the air is circulated with an oscillating fan(s). In an enclosed grow room, HID lamps and ballasts keep the area warm. A remote ballast placed near the floor on a shelf or a stand also helps break up air stratification by radiating heat upward. Grow rooms in cool climates stay warm during the day when the outdoor temperature peaks, but often cool off too much at night when cold temperatures set in. To compensate, growers turn on the lamp at night to help heat the room, but leave it off during the day.

Sometimes it is too cold for the lamp and ballast to maintain satisfactory room temperatures. Grow rooms located in homes are usually equipped with a central heating and/or air conditioning vent. The vent is usually controlled by a central thermostat that regulates the temperature of the home. By adjusting the thermostat to 72°F (22°C) and opening the door to the grow room, it can stay a cozy 72°F (22°C). However, using so much power is expensive, and could cause a security quandary. Keeping the thermostat between 60 and 65°F (15-18°C), coupled with the heat from the HID system, should be enough to sustain 75°F (24°C) temperatures. Other supplemental heat sources such as inefficient incandescent lightbulbs and electric heaters are expensive and draw extra electricity, but they provide instant heat that is easy to regulate. Propane and natural gas heaters increase

temperatures and burn oxygen from the air, creating CO₂ and water vapor as by-products. This dual advantage makes using a CO₂ generator economical and practical.

Kerosene heaters also work to generate heat and CO₂. Look for a heater that burns its fuel efficiently and completely with no tell-tale odor of the fuel in the room. Do not use old kerosene heaters or fuel-oil heaters if they burn fuel inefficiently. A blue flame is burning all the fuel cleanly. A red flame indicates only part of the fuel is being burned. I'm not a big fan of kerosene heaters and do not recommend using them. The room must be vented regularly to avoid buildup of toxic carbon monoxide, also a by-product of combustion.

Diesel oil is a common source of indoor heat. Many furnaces use this dirty, polluting fuel. Wood heat is not the cleanest either, but works well as a heat source. A vent fan is extremely important to exhaust polluted air and draw fresh air into a room heated by an oil furnace or woodstove.

Insect populations and fungi are also affected by temperature. In general, the cooler it is, the slower the insects and fungi reproduce and develop. Temperature control is effectively integrated into many insect and fungus control programs. Check recommendations in Chapter 14, "Pests, Fungi and Diseases."

Humidity

Humidity is relative; that is, air holds different quantities of water at different temperatures. Relative humidity is the ratio between the amount of moisture in the air and the greatest amount of moisture the air could hold at the same temperature. In other words, the hotter it is, the more moisture air can hold; the cooler it is, the less moisture air can hold. When the temperature in a grow room drops, the humidity climbs, and moisture condenses. For example, an 800 cubic foot (10 × 10 × 8 feet) (21.5 m³) grow room will hold about 14 ounces (414 ml) of water when the tempera-

ture is 70°F (21°C) and relative humidity is at 100 percent. When the temperature is increased to 100°F (38°C), the same room will hold 56 ounces (1.65 L) of moisture at 100 percent relative humidity. That is four times more moisture! Where does this water go when the temperature drops? It condenses, onto the surface of plants and grow-room walls, just as dew condenses outdoors.

Relative humidity increases when the temperature drops at night. The greater the temperature variation, the greater the relative humidity variation will be. Supplemental heat or extra ventilation is often necessary at night if temperatures fluctuate more than 15°F (8°C).

Seedlings and vegetative plants grow best when the relative humidity is from 65 to 70 percent. Flowering plants grow best in a relative humidity range from 55 to 60 percent. The lower humidity discourages diseases and pests. As with temperature, consistent humidity promotes healthy, even growth. Relative humidity level affects the transpiration rate of the stomata. When humidity is high, water evaporates slowly. The stomata close, transpiration slows, and so does plant growth. Water evaporates quickly into drier air causing stomata to open, increasing transpiration, fluid flow, and growth. Transpiration in arid conditions will be rapid only if there is enough water available for roots to draw in. If water is inadequate, stomata will close to protect the plant from dehydration, causing growth to slow.

When the relative humidity climbs beyond 70 percent, the pressure outside the leaf is too high and inside too low. This causes the stomata to close, which slows growth. For example, a 40-inch (1 m) tall plant can easily transpire a gallon (4 L) per day when the humidity is below 50 percent. However, the same plant will transpire about a half-pint (0.5 L) on a cool humid day.

A 10 × 10 × 8 foot (800 cubic feet) (21.5 m³) grow room can hold:

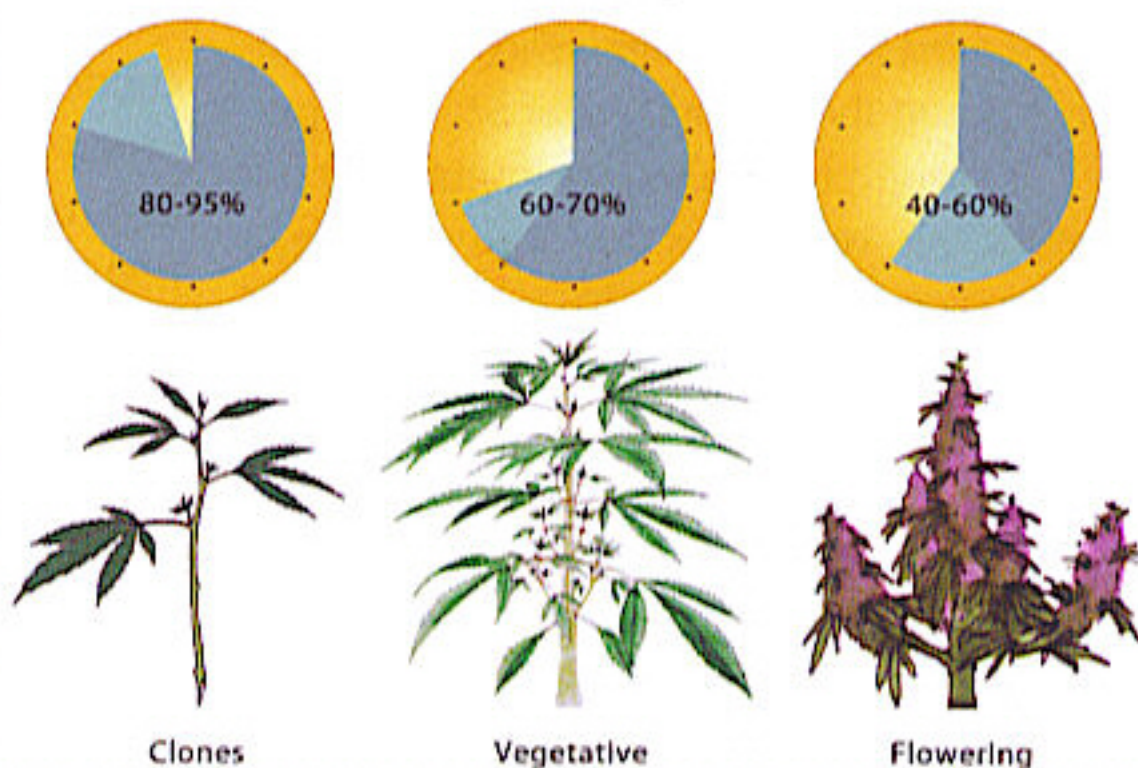
4 oz (118 ml) of water at 32°F (0°C).
7 oz (207 ml) of water at 50°F (10°C).
14 oz (414 ml) of water at 70°F (21°C).
18 oz (532 ml) of water at 80°F (26°C).
28 oz (828 ml) of water at 90°F (32°C).
56 oz (1.65 L) of water at 100°F (38°C).

The moisture holding capacity of air doubles with every 20°F (10°C) increase in temperature.



A maximum/minimum digital hygrometer registers the high and low humidity as well as current humidity.

Humidity



This is the best relative humidity range for clones, as well as vegetative and flowering plants.



Air conditioners cool and dehumidify grow rooms. Growers must weigh the benefits against the extra electricity they use.

Measuring Relative Humidity

Relative humidity control is an integral part of insect and fungus prevention and control. Humidity above 80 percent discourages spider mites but promotes fungus as well as root and stem rot. Humidity levels below 60 percent reduce the chances of fungus and rot.

Measure relative humidity with a hygrometer. This extremely important instrument will save you and your garden much frustration and fungi. By knowing the exact moisture content in the air, humidity may be adjusted to a safe 55 to 60 percent level that encourages transpiration and discourages fungus growth.

There are two common types of hygrometers. The spring type is accurate within 5 to 10 percent. This hygrometer is inexpensive and adequate for most hobby growers whose main concern is to keep the humidity near 55 to 60 percent. The second type, a psychrometer, is more expensive but very accurate. A psychrometer that measures relative humidity with a wet and dry bulb is an excellent way to keep an accurate vigil on relative humidity. Today there are many exceptionally accurate high-tech gadgets, plus they are equipped with memory!

A humidistat is similar to a thermostat, but regulates humidity instead of temperature. Humidistats are wonderful and make controlling the environment very easy. Humidistats cost

less than \$100 and are worth their weight in resin glands. A humidistat and thermostat can be wired "in line" to control a vent fan. Each can operate the fan independently. As soon as the humidity (or temperature) exceeds the acceptable range, the fan turns on to vent the humid (or hot) air outdoors.

The HID lamp and ballast radiate heat, which lowers humidity. Heat from the HID system and a vent fan on a thermostat/humidistat are all the humidity control necessary for most grow rooms. Other dry heat sources, such as hot air vented from a furnace or wood stove, dry the air and lower the humidity. Be careful. Do not let piped-in, warm, dry air blow directly on foliage. It will rapidly dehydrate plants.

Increase humidity by misting the air with water or setting out a bucket of water to evaporate into the air. A humidifier is convenient and relatively inexpensive. Humidifiers evaporate water into the air to increase humidity. Just set the dial to a specific humidity, and presto! The humidity changes to the desired level as soon as the humidifier is able to evaporate enough water into the air. A humidifier is not necessary unless there is an extreme problem with the grow room drying out. Problems seldom occur that can be remedied by a humidifier. All too often, there is too much humidity in the air as a result of irrigation and transpiration. If a ventilation system is unable to remove enough air to lower humidity, a dehumidifier could be just the ticket!

A dehumidifier removes moisture in a room by condensing it from the air. Once the water is separated from the air, it is captured in a removable container. This container should be emptied daily. It is easy to remove and catch 10 ounces (0.3 L) of water in a 10 × 10 × 8-foot (21.5 m²) room when the temperature drops just 10°F (5°C).

A dehumidifier can be used anytime to help guard against fungus. Just set the dial at the desired percent humidity and presto, perfect humidity. Dehumidifiers are more complex, use more electricity than humidifiers, and cost more,

but to growers with extreme humidity problems not yet cured by a vent fan, they are worth the added expense. The best prices on dehumidifiers have been found at Home Depot, Home Base, and other discount stores. Check the rental companies in the Yellow Pages for large dehumidifiers if only needed for a short time. Air conditioners also function as dehumidifiers but use a lot of electricity. The water collected from a dehumidifier or air conditioner has a very low EC and can be used to water plants.

Note: Air conditioners draw moisture from the air and lower the humidity. The moisture condenses into water that is collected in a container or expelled through a tube outdoors. The condensed water carries the fragrance of cannabis. Sniffer dogs can easily smell the fragrance of cannabis in the "tainted" water expelled outdoors.

Rooting clones thrive when the humidity is from 70 to 100 percent. Under arid conditions, the undeveloped root system is not able to supply water fast enough to keep clones alive. See "Cloning" for more specific information on humidity levels during different stages of cloning.

CO₂ Enrichment

Carbon dioxide (CO₂) is a colorless, odorless, non-flammable gas that is around us all the time. The air we breathe contains 0.03-0.04 percent CO₂. Rapidly growing cannabis can use all of the available CO₂ in an enclosed grow room within a few hours. Photosynthesis and growth slow to a crawl when the CO₂ level falls below 0.02 percent.

Carbon dioxide enrichment has been used in commercial greenhouses for more than 35 years. Adding more CO₂ to grow room air stimulates growth. Indoor cannabis cultivation is similar to conditions in a greenhouse, and indoor growers apply the same principles. Cannabis can use more CO₂ than the 0.03-0.04 percent (300-400 ppm) that naturally occurs in the air. By increasing the amount of CO₂ to

0.12-0.15 percent (1200-1500 ppm)—the optimum amount widely agreed upon by professional growers—plants can grow up to 30 percent faster, providing that light, water, and nutrients are not limiting. Carbon dioxide enrichment has little or no affect on plants grown under fluorescent lights. Fluorescent tubes do not supply enough light for the plant to process the extra available CO₂.

*Carbon dioxide can make people woozy when it rises above 5000 ppm and can become toxic at super high levels. When CO₂ rises to such high levels, there is always a lack of oxygen!

Carbon dioxide enrichment does not make plants produce more potent THC; it causes more foliage to grow in less time. The larger the volume of THC-potent cannabis, the larger the volume of THC produced.

Carbon dioxide-enriched cannabis demands a higher level of maintenance than normal plants. Carbon dioxide-enriched plants use nutrients, water, and space faster than non-enriched plants. A higher temperature, from 75 to 80°F (24 to 26°C) will help stimulate more rapid metabolism within the super-enriched plants. When temperatures climb beyond 85°F (29°C), CO₂ enrichment becomes ineffective, and at 90°F (32°C) growth stops.

Carbon dioxide-enriched plants use more water. Water rises from plant roots and is released into the air by the same stomata the plant uses to absorb CO₂ during transpiration. Carbon dioxide enrichment affects transpiration by causing the plants' stomata to partially close. This slows down the loss of water vapor into the air. Foliage on CO₂-enriched plants is measurably thicker, more turgid, and slower to wilt than leaves on non-enriched plants.

Carbon dioxide affects plant morphology. In an enriched growing environment, stems and branches grow faster, and the cells of these plant parts are more densely packed. Flower stems carry more weight without bending. Because of the increased rate of branching,



Inexpensive electronic components have made it possible for manufacturers to lower the price on CO₂ monitors.

cannabis has more flower initiation sites. Plants that sometimes do not bear from the first flower set are more likely to set flowers early if CO₂ enrichment is used.

With CO₂-enriched air, plants that do not have the support of the other critical elements for life will not benefit at all, and the CO₂ is wasted. The plant can be limited by just one of the critical factors. For example, the plants use water and nutrients a lot faster, and if they are not supplied, the plants will not grow. They might even be stunted.

To be most effective, the CO₂ level must be maintained at 1000 to 1500 ppm everywhere in the room. To accomplish this, the grow room must be completely enclosed. Cracks in and around the walls should be sealed off to prevent CO₂ from escaping. Enclosing the room makes it easier to control the CO₂ content of the air within. The room must also have a vent fan with flaps or a baffle. The vent fan will remove the stale air that will be replaced with CO₂-enriched

air. The flaps or baffle will help contain the CO₂ in the enclosed grow room. Venting requirements will change with each type of CO₂-enrichment system and are discussed below.

Measuring CO₂

Measuring and monitoring CO₂ levels in the air is rather expensive and often unnecessary for small growers. Monitoring CO₂ levels in grow rooms with ten or more lights really helps keep the levels consistent.

Disposable comparative colorimetry CO₂ test kits are easy to use, accurate, and inexpensive. The test kits contain a syringe and test tubes and sell for about \$30. To use the kit, break off each end tip of the test tube, and insert one end into the closed syringe. Pull 100 cubic centimeters into the syringe, and note the blue color change in the cylinder where the active ingredient reacts with the CO₂ in the air drawn through the cylinder. These kits are reliable to within 40 ppm.

Electrochemical sensing systems measure electrical conductivity of an air sample in either an alkali solution or distilled or de-ionized water. These systems are relatively inexpensive, but they have drawbacks: limited accuracy and sensitivity to temperature and air pollutants.

Infrared monitoring systems are more accurate and versatile. They correctly measure CO₂ and can be synchronized with controllers that operate heat, ventilation, and CO₂ generators. Even though the initial cost for a monitor is high, they can solve many CO₂ problems before they occur and can ensure optimum growing conditions. Specialty indoor garden stores sell the monitors for less than \$1000.

Growers who do not want to spend the time and energy required to monitor CO₂ can use a set of scales and simple mathematics to determine the approximate amount of CO₂ in the air, but this calculation does not account for ventilation, air leaks, and other things that could skew the measurement. It is easier to measure the amount of CO₂ produced rather than to measure the amount of CO₂ in the grow room's atmosphere.

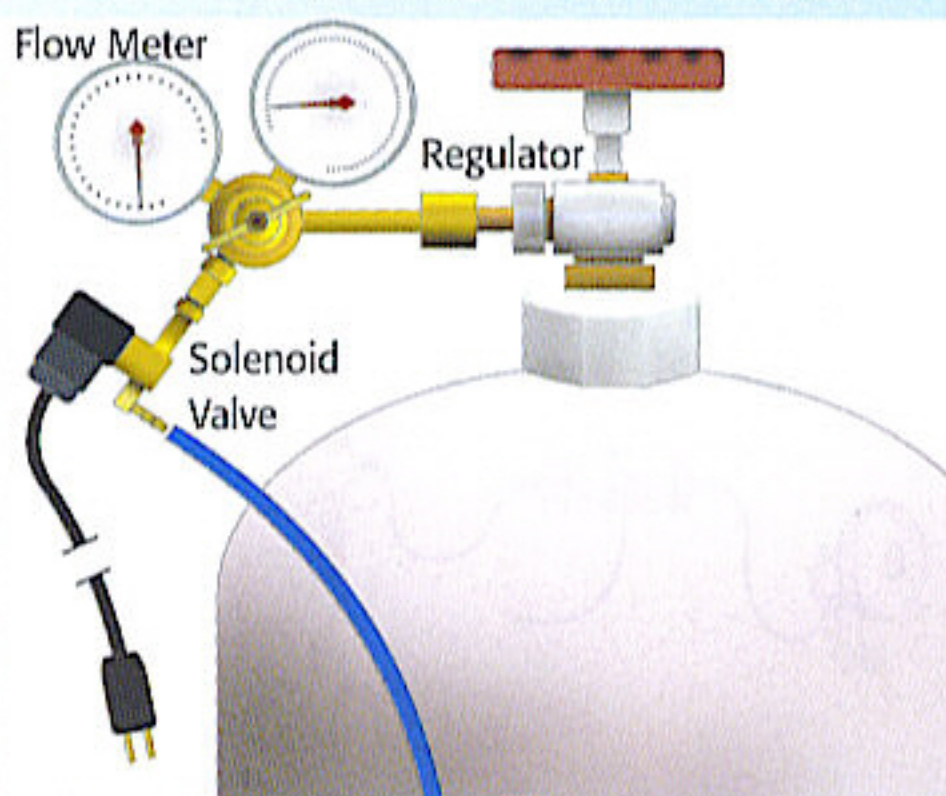
To measure the amount of fuel used, simply weigh the tank before it is turned on, use it for an hour, and then weigh it again. The difference in weight is the amount of gas or fuel used. See the calculations below for more information on calculating the amount of CO₂ in the room.

Producing CO₂

There are many ways to raise the CO₂ content of an enclosed grow room. The two most popular ways are to disperse it from a tank or burn a fuel to manufacture it. Carbon dioxide is one of the byproducts of combustion. Growers can burn any fossil (carbon-based) fuel to produce CO₂ except for those containing sulfur dioxide and ethylene, which are harmful to plants. Carbon dioxide gas is a by-product of fermentation and organic decomposition. The CO₂ level near the ground of a rain forest covered with decaying organic matter could be two to three times as high as normal, but bringing a compost pile inside to cook down is not practical. Dry ice is made from frozen CO₂. The CO₂ is released when dry ice comes in contact with the atmosphere. It can get expensive and be a lot of trouble to keep a large room constantly supplied with dry ice. It is difficult to calculate how much CO₂ is released into the air by fermentation, decomposition, or dry ice without purchasing expensive equipment.

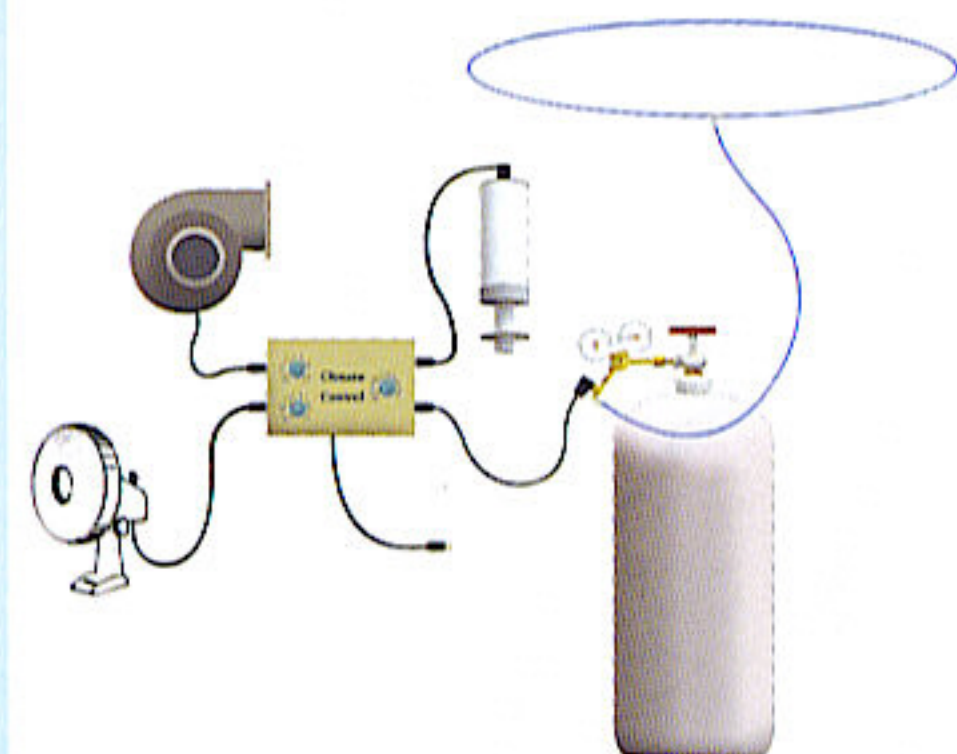
CO₂ Emitter Systems

Compressed CO₂ systems are virtually risk-free, producing no toxic gases, heat, or water. These systems are also precise, metering an exact amount of CO₂ into the room. Carbon dioxide is metered out of a cylinder of the compressed gas using a regulator, flow meter, a solenoid valve, and a short-range timer. Two types of systems are: continuous flow and short range. Metal carbon dioxide cylinders which hold the gas under 1000 to 2200 pounds of pressure per square inch (psi) (depending upon temperature) can be purchased from welding or beverage supply stores. The cylinders are often available at



When open, the red on/off valve on top supplies compressed CO₂ via the regulator and flow meter. An electric solenoid valve controls the timed bursts of CO₂ gas.

hydroponic stores. In North America, cylinders come in three sizes: 20, 35, and 50 pounds (9, 16, and 23 kg), and average between \$100 and \$200 (with refills costing about \$30). Tanks must be inspected annually and registered with a nationwide safety agency. Welding suppliers and beverage suppliers often require identification such as a driver's license. Most suppliers exchange tanks and refill them. Fire extinguisher companies and beverage supply companies normally fill CO₂ tanks on the spot. If you purchase a lighter and stronger aluminum tank, make sure to request an aluminum tank exchange. Remember, the tank you buy is not necessarily the one you keep. To experiment before purchasing equipment, rent a 50-pound (23 kg) tank. A large 50-pound (23 kg) cylinder is heavier but saves you the time of returning to the store to have it refilled. When full, a 50-pound steel tank weighs 170 pounds (77 kg). A full 20-pound (9 kg) steel tank weighs 70 pounds (32 kg) and might be too heavy to carry up and down stairs. A full 20-pound (9 kg) aluminum tank weighs about 50 pounds (23 kg), and a full 35-pound (16 kg) tank weighs 75 pounds (34 kg). Make sure CO₂ tanks have a protective collar on top to shield the valve. If the valve is knocked off by an accidental fall, there is



A set-up consists of a tank of CO₂ gas, regulator, solenoid valve, and a flow meter.

enough pressure to send the top (regulator, flow meter, valve, etc.) straight through a parked car.

Buying a complete CO₂ emitter system at a hydroponic store is the best option for most closet growers. These systems offer a good value for small indoor growers. You can make your own system as described below, but these systems often cost more than the pre-manufactured models.

Welding suppliers also carry regulators, and flow meters. Flow meters reduce and control the cubic feet per hour (cfh). The regulator controls the psi. Models with smaller flow rates, 10 to 60 cfh, are preferable for gardening purposes. Buy a quality regulator-flow meter. Buy all components at the same time, and make sure they are compatible.

Carbon dioxide is very cold when released from a bottle where it has been kept under pressure. Even a quick blast can do damage to skin or eyes. If the flow rate is above 20 cfh, your regulator might freeze.

A regulator and flow valve is essential, but the solenoid valve and the timer are optional. However, growers who do not use a solenoid valve and timer waste CO₂. The solenoid valve and timer regulate the flow of CO₂. A solenoid valve is electrically operated and is used to start and stop the gas flow from the regulator and

flow meter. The least expensive timer is plastic and is commonly used for automatic sprinkler systems, but 240-, 115-, 24- and 12-volt systems are available. They cost about the same, but the lower voltages offer added safety from electrical shock.

To automate the system, you need a "short range" digital timer to open the solenoid valve for brief periods several times a day.

Control the exact amount of CO₂ released into the garden room by altering the flow and duration of CO₂. To determine how long the valve should remain open, divide the number of cubic feet of gas required by the flow rate. If the flow meter is set at 10 cfh, the valve will need to be open for 0.1 hours (1 divided by 10) or 6 minutes (0.1 hour × 60 minutes) to bring the room up to 1500 ppm. Remember, CO₂ leaks out of the grow room. On average, the CO₂ level of the room returns to 300 ppm in about three hours due to plant usage and room leakage. To maintain a steady level of CO₂, split the amount of CO₂ released per hour into two or four smaller increments dispersed more frequently.

Distribute the CO₂ from the tank to the grow room by using a tube or fan. Suspend lightweight perforated plastic from the ceiling to disperse the CO₂. The tubing carries CO₂ from the supply tank to the center of the grow room. The main supply line is attached to several smaller branches that extend throughout the garden. CO₂ is heavier and cooler than air and cascades onto the plants below.

To make sure the CO₂ is dispersed from the tubing evenly, submerge the lightweight plastic tubing in water and punch the emission holes under water while the CO₂ is being piped into the line. This way you know the proper diameter holes to punch and where to punch them to create the ideal CO₂ flow over the garden.

Overhead fans help distribute CO₂ evenly throughout the room. The CO₂ is released directly below the fan into its airflow. This evenly mixes the CO₂ throughout the air and keeps it recirculating across the plants.

Compressed CO_2 is expensive, especially in large grow shows. At roughly \$0.50 per pound (450 gm), compressed gas is much more expensive than fuels used in generators. Cost of equipment and fuel make compressed CO_2 enrichment systems less economical than generators.

CO_2 Generator Systems

CO_2 generators are used by commercial flower, vegetable, and marijuana growers. Green Air Products has introduced a complete line of reasonably priced CO_2 generators that burn natural gas or LP (propane) to produce CO_2 . However, heat and water are by-products of the combustion process. Generators use a pilot light with a flow meter and burner. The inside of the generator is similar to a gas stove burner with a pilot light enclosed in a protective housing. The generator must have a cover over the open flame. You can operate the generators manually or synchronize them with a timer to operate with other grow room equipment such as ventilation fans.

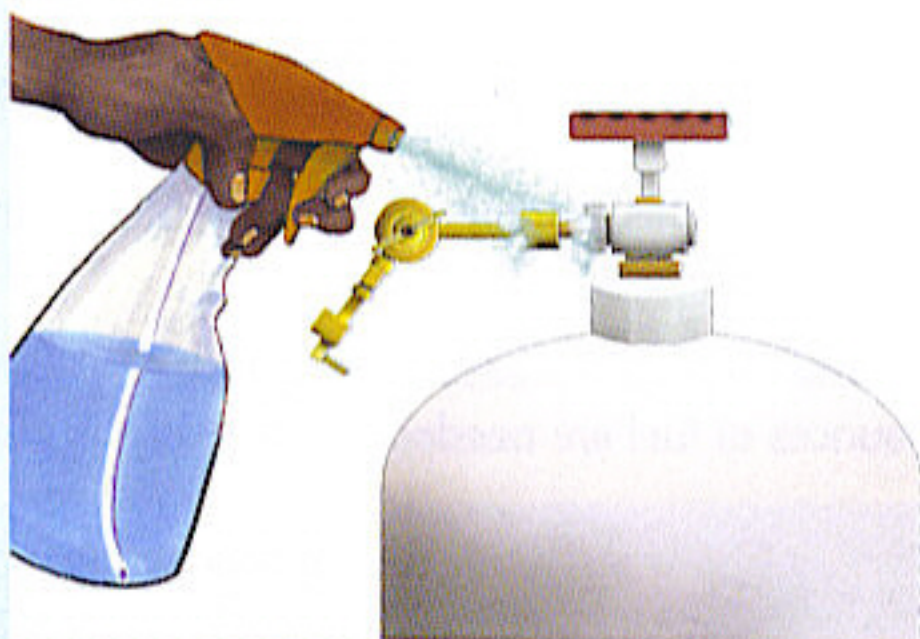
CO_2 generators produce hot exhaust gasses ($\text{CO}_2 + \text{H}_2\text{O}$). Even though CO_2 is heavier than air, it is hotter and therefore less dense and rises in a garden room. You must have good air circulation for even distribution of CO_2 .

Carbon Dioxide generators can burn any fossil fuel—kerosene, propane, or natural gas. Low grades of kerosene can have sulfur content as high as 0.01 of 1 percent, enough to cause sulfur dioxide pollution. Use only high-quality kerosene even though it is expensive. Always use grade "1-K" kerosene. Maintenance costs for kerosene generators are high, because they use electrodes, pumps, and fuel filters. For most grow rooms, propane and natural gas burners are the best choice.

When filling a new propane tank, first empty it of the inert gas which is used to protect it from rust. Never completely fill a propane tank. Propane expands and contracts with temperature change and could release flammable gas from the pressure vent if too full.



CO_2 generators produce carbon dioxide by burning LP or propane gas. They also generate heat and water vapor as by-products.



Spray soapy water around all propane gas connections to check for bubbles (leaks).

Generators burn either propane or natural gas, but must be set up for one or the other. They are inexpensive to maintain and do not use filters or pumps. Hobby CO_2 generators range from \$300 to \$500, depending on size. The initial cost of a generator is slightly higher than a CO_2 emitter system that uses small, compressed-gas cylinders. Nonetheless, growers prefer propane and natural gas generators, because they are about four times less expensive to operate than bottled CO_2 generators. One gallon of propane, which costs about \$2, contains 36 cubic feet of gas and over 100 cubic feet of CO_2 (every cubic foot of propane gas produces 3 cubic feet of CO_2). For example, if a garden used one gallon of propane every day, the cost would be about

1 pound of CO₂ displaces 8.7 cubic feet (246 cm³) of CO₂.
 0.3 pound (0.135 kg) of fuel produces 1 pound (454 gm) of CO₂.

Divide the total amount of CO₂ needed by 8.7 and multiply by 0.33 to determine the amount of fuel needed. In our example on pages 18-19, we found we need 1 cubic foot of CO₂ for an 800 cubic foot garden room.

$L \times W \times H = \text{room volume (cubic feet)}$
 $12 \times 14 \times 8 = 1344 \text{ cubic feet (38 m}^3\text{)}$

Desired CO₂ level is 1200 ppm (0.0012 ppm)*
 Multiply room volume by 0.0012 = desired CO₂ level
 $1344 \text{ cubic feet (38 m}^3\text{)} \times 0.0012 = 1.613 \text{ cubic feet (46 cm}^3\text{) CO}_2$

1 pound (0.45 kg) of fuel burned = three pounds (1.35 kg) of CO₂ gas
 0.33 pound (0.148 kg) fuel burned = one pound CO₂ gas

$0.33 \times 1.613 = 0.56 \text{ pounds of CO}_2 \text{ fuel to burn to bring the CO}_2 \text{ level to 1200 ppm.}$

Three times this amount ($0.53 \times 3 = 1.59 \text{ pounds}$) of fuel will create enough CO₂ for the room for 12-18 hours.

Convert this into ounces by multiplying by 16 (there are 16 ounces in a pound). $.037 \times 16 = 0.59 \text{ ounces of fuel are needed for every injection.}$

Check out www.onlineconversion.com to convert to or from the English and Metric Systems.

\$60 per month. In contrast, bottled CO₂ for the same room would cost more than \$200 per month!

CO₂ generators are less expensive to maintain and less cumbersome, but they have some disadvantages, too. One pound of fuel produces 1.5 pounds of water and 21,800 Btu of heat. For grow rooms less than 400 cubic feet, this makes generators unusable. Even for larger garden rooms, the added heat and humidity must be carefully monitored and controlled so as not to affect plants. Growers in warm climates do not use generators, because they produce too much heat and humidity.

If fuel does not burn completely or cleanly, CO₂ generators can release toxic gases—including carbon monoxide—into the grow room.

Nitrous oxide, also a byproduct of burning propane, can grow to toxic levels, too. Well-made CO₂ generators have a pilot and timer. If leaks or problems are detected, the pilot and timer will turn off.

A CO₂ monitor is necessary if you are sensitive to high levels of the gas. Digital alarm units or color change plates (used in aircraft) are an economical alternative. Carbon monoxide is a deadly gas and can be detected with a carbon monoxide alarm available at most hardware and building supply stores.

Check homemade generators frequently, including kerosene or gas heaters. Propane and natural gas produce a blue flame when burning efficiently. A yellow flame means unburned gas (which creates carbon monoxide) and needs

more oxygen to burn cleanly. Leaks in a system can be detected by applying a solution of equal parts water and concentrated dish soap to all connections. If bubbles appear, gas is leaking. Never use a leaky system.

Oxygen is also burned. As it becomes deficient in the room, the oxygen/fuel mixture changes. The flame burns too rich and yellows. This is why fresh air is essential.

Turn off CO₂ generators at night. They create excess heat and humidity in the grow room, and they need oxygen to operate. At night, roots need the extra oxygen in the room for continued growth.

If you are using CO₂ and the yield does not increase, check to make sure the entire grow room is running properly and that plants have the proper light and nutrient levels, as well as the correct temperature, humidity, grow-medium moisture, and pH. Make sure roots receive enough oxygen both day and night.

Other Ways to Make CO₂

There are many ways to make CO₂. You can enrich small areas by burning ethyl or methyl alcohol in a kerosene lamp. Norwegians are studying charcoal burners as a source of CO₂. When refined, the system will combine the advantages of generators and compressed gas. Charcoal is much less expensive than bottled CO₂ and is less risky than generators in terms of toxic by-products. Others are studying the use of new technology to extract or filter CO₂ from the air.

This little inexpensive puck called Excellofizz (www.fearlessgardener.com) releases CO₂ into the atmosphere. It is simple to use; just add a few ounces of water and a puck or two to cause a chemical reaction that will disperse enough CO₂ to augment the air in a 10-foot-square (9 m²) room to about 1000 ppm all day. It also releases a eucalyptus fragrance to help mask odors. Make sure to keep the fizz contained, and if using an ozone generator, keep the lamp clean.



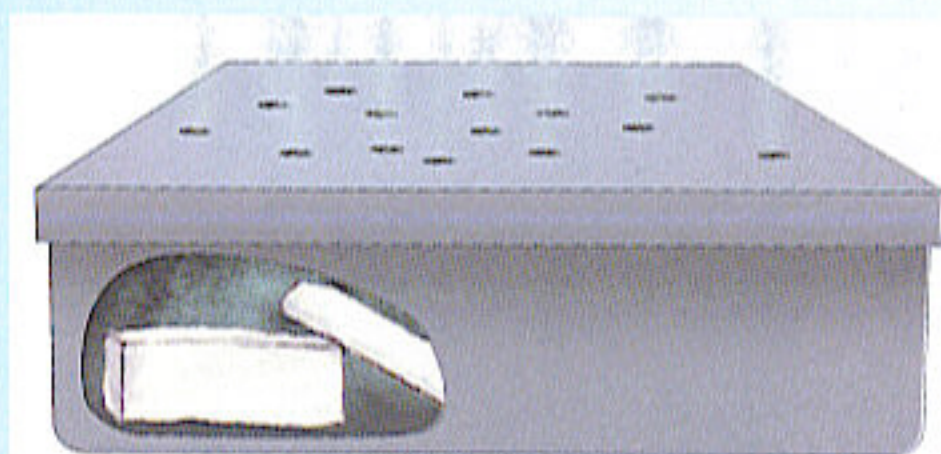
The Excellofizz puck is a low-cost product that releases CO₂ when it is bathed in water.

Compost and Organic Growing Mediums

Decomposing organic materials like wood chips, hay, leaves, and manures release large amounts of CO₂. Although you can capture CO₂ from this decomposition, it is most often impractical for indoor growers. Piping indoors the CO₂ and fumes from a compost pile is complicated, expensive, and more work than it is worth.

Fermentation

Small-scale growers use fermentation to produce CO₂. Combine water, sugar, and yeast to produce CO₂. The yeast eats the sugar and releases CO₂ and alcohol as by-products. Growers who brew beer at home can use a small-scale system to increase the CO₂ levels in a room. Non-brewers can mix one cup of sugar, a packet of brewer's yeast, and three quarts of warm water in a gallon jug to make CO₂. You will have to experiment a little with the water temperature to get it right. Yeast dies in hot water and does not activate in cold water. Once the yeast is activated, CO₂ is released into the air in bursts. Punch a small hole in the cap of the jug, and place it in a warm spot (80 to 95°F [26 to 34°C]) in your grow room. Many gardeners buy a fermentation lock (available for under \$10



Put dry ice in a plastic container with holes to slow evaporation of CO₂ gas.

at beer-brewing stores). Such locks prevent contaminants from entering the jug, and they bubble CO₂ through water so the rate of production can be observed. The hitch is that you must change the concoction up to three times a day. Pour out half the solution, and add 1.5 quarts (1.4 L) of water and another cup (24 cl) of sugar. As long as the yeast continues to grow and bubble, the mixture can last indefinitely. When the yeast starts to die, add another packet. This basic formula can be adapted to make smaller or larger-scale fermenters. Several jugs scattered around the garden room have a significant impact on CO₂ levels.

Fermentation is an inexpensive alternative to produce CO₂. It releases no heat, toxic gases, or water and uses no electricity. But because it stinks, it is unlikely that a gardener could tolerate a large-scale fermentation process. In addition, it is difficult to measure CO₂ production from this system, making it difficult to maintain uniform levels throughout the day.

Dry Ice

Dry ice gets very expensive with prolonged use. Two pounds of dry ice will raise the CO₂ level in a 10 × 10-foot (3 m²) grow room to about 2000 ppm for a 24-hour period. One chagrined grower remarked, "I can't believe that stuff melts so fast."

Growers have long used large, insulated tanks filled with dry ice to add CO₂. Dry ice is carbon dioxide that has been chilled and compressed. As it melts, it changes from solid to gas. Gaseous CO₂ can be mixed into the air with fans that circulate it among the plants. Dry ice works well on

a smaller scale without a tank and converter. It is readily available (check out the Yellow Pages) and inexpensive. Because CO₂ has no liquid stage, the transformation from solid to gas as the ice melts is clean and tidy. It's also easy to approximate the amount of CO₂ being released. A pound of dry ice is equal to a pound of liquid CO₂. Determining the thawing period for a particular size of dry ice will allow you to estimate how much CO₂ is released during a particular time period. To prolong the thawing process, put dry ice in insulating containers such as foam ice coolers, and cut holes in the top and sides to release the CO₂. The size and number of holes allow you to control the rate at which the block melts and releases CO₂.

Dry ice is economical and risk free; it releases no toxic gases, heat, or water. Although dry ice is easier to handle than compressed CO₂ tanks, it is difficult to store. The melting can be slowed through insulation, but it cannot be stopped. Because it is extremely cold, dry ice can also cause tissue damage or burn the skin after prolonged contact.

Baking Soda and Vinegar

Consider using vinegar and baking soda to produce CO₂ in a small grow room. This method eliminates excess heat and water vapor production and requires only household items. Create a system that drips vinegar (acetic acid) into a bed of baking soda. The main disadvantage of this system is the erratic level of CO₂ produced. It takes a considerable amount of time for the CO₂ to build up to a level where it helps plants. However, once it reaches an optimum level, it can continue to rise until it reaches levels detrimental to plants. If you have time to experiment, it is possible to set up a drip system operated by a solenoid valve and a short-term timer. With such a system, CO₂ could be released periodically in small increments and coordinated with ventilation schedules.

Note: Some recipes replace vinegar with muriatic (hydrochloric) acid. I advise using vinegar, because hydrochloric acid is very dangerous. It

can burn flesh, eyes, and respiratory system; it can even burn through concrete.

Odor

A good exhaust fan, vented outdoors, is the first step in cannabis odor control and the easiest way to keep the house from reeking of fresh marijuana. If the odor is strong and venting is a problem, a negative ion generator (deionizer); deodorizing liquid, gel, puck, or spray; ozone generator; activated charcoal filter; or a combination of two or more of these will solve fragrance problems.

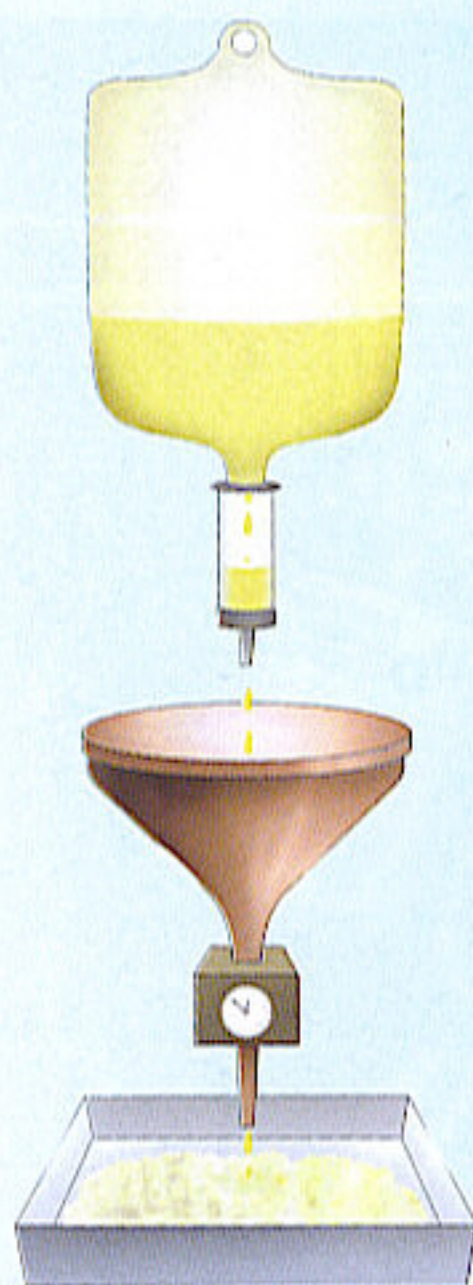
Deodorizers

Kill odors by changing their structure at the molecular level. Products such as Odor Killer™, Ona™, VaporTek™, and Ozium™, are made from essential oils that kill odors by creating a neutral atmosphere at the atomic level. Such products are usually available in gel and spray. Many growers prefer to use the gel over the long term and spray for emergency situations, such as when unexpected guests stop by during harvest.

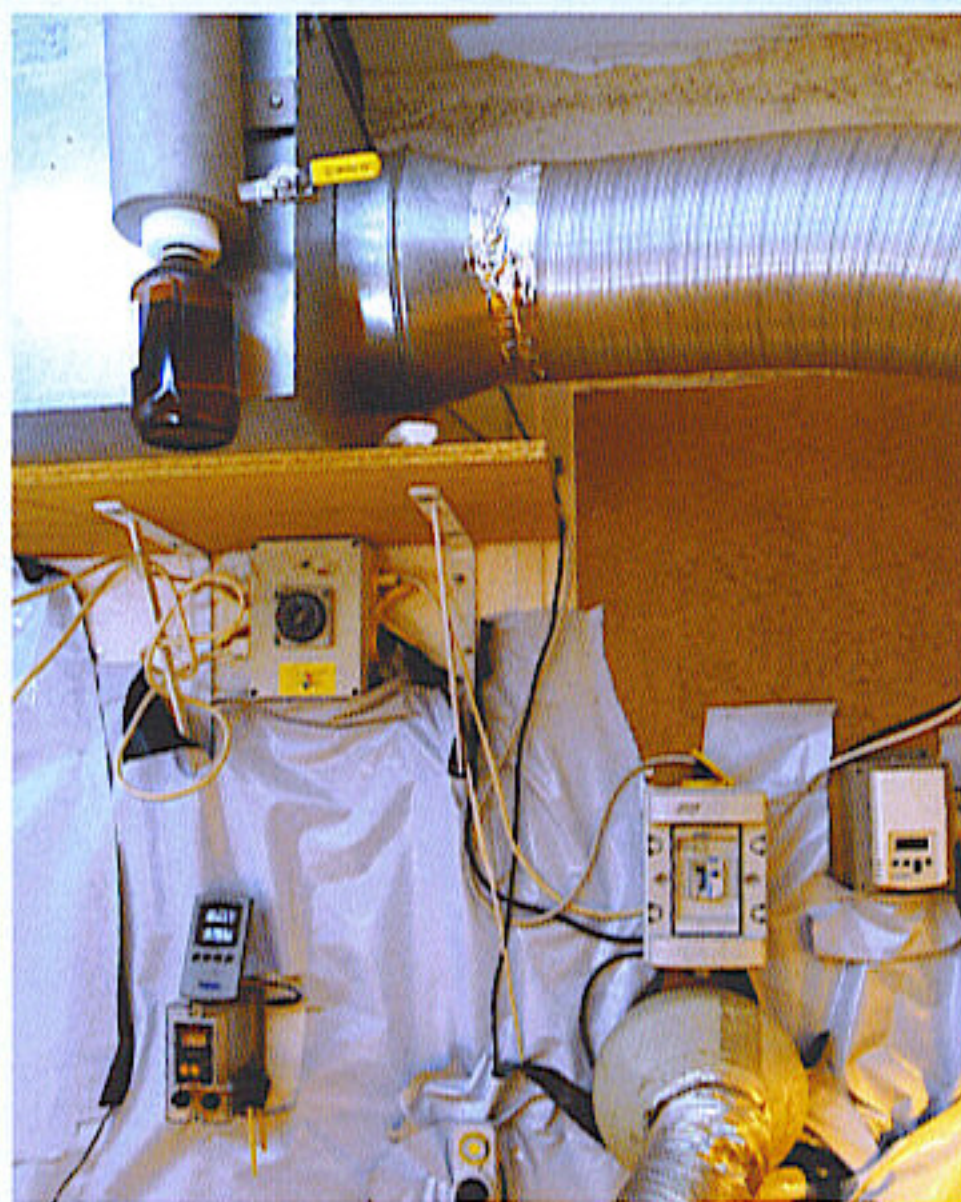
The deodorizers can be set out in the room, around the house, and near doorways. Several companies offer products that stick to the wall. One ingenious grower I interviewed stuck one such deodorizing puck to the inside of the front door, just below the mail slot to keep the house fresh. Other products are designed to be attached to the ventilation ductwork system. Often these products are used not only to alter the odor of marijuana, but also to alter the tell-tale odor produced by an ozone generator. Other companies offer aerosol spray cans with a dispenser that periodically meters out a burst of spray.

Negative Ion Generators

Negative ion generators are small and somewhat efficient to control odors, smoke, airborne pollen, mold, dust, and static electricity. They pump negative ions into the atmosphere. The negative ions are attracted to positive ions containing odors and other airborne pollutants. The



Although a bit of a trick to keep going all the time, pouring vinegar on baking soda is a fair source of CO₂.



Some gardeners prefer to use essential oils to overpower fragrance. Such products are available in liquid, gel, and spray forms.



Fan with deodorizer



This grower treats the air with ozone and deodorizes air again just before it is expelled.

negative ions attach to positive ions, and the odor becomes neutralized. The particles fall to the floor and create a fine covering of dust on the ground, walls, and objects in the room. These devices work fairly well for small grow rooms with minimal odor problems. The generator uses very little electricity and plugs into a regular 115-volt current. Visually check the filter every few days, and make sure to keep it clean.

Ozone Generators

Ozone has many applications including food and water sterilization and removing odors from the air at the molecular level. Some growers even use high levels of ozone to exterminate grow room pests.

Ozone generators neutralize odors by converting oxygen (O_2) into ozone (O_3) by exposing the stinky air to ultraviolet (UV) light. The extra molecule is always a positively charged ion that is predisposed to attach to a negatively charged ion (anion). Odors are negatively charged anions. When the extra oxygen ion attaches to the anion, they neutralize one another and the odor, too. Once the extra molecule is shed, O_3 is converted back into O_2 . The chemistry takes a minute or longer to occur, so treated air must be held in a chamber to be converted effectively.

Ozone has an unusual odor similar to the smell of the air after a good rain. Anybody who



Ozone generators are rated by the number of cubic feet (m^3) they are able to treat.

has ever smelled the air in a room recently treated with ozone knows the smell and will never forget it. Make sure not to produce too much ozone, and give it enough time to mix with smelly air to neutralize odors. The distinctive odor of excess ozone exiting a building will tip off narcs and thieves. For this reason, many growers also use a carbon filter to further scrub the air.

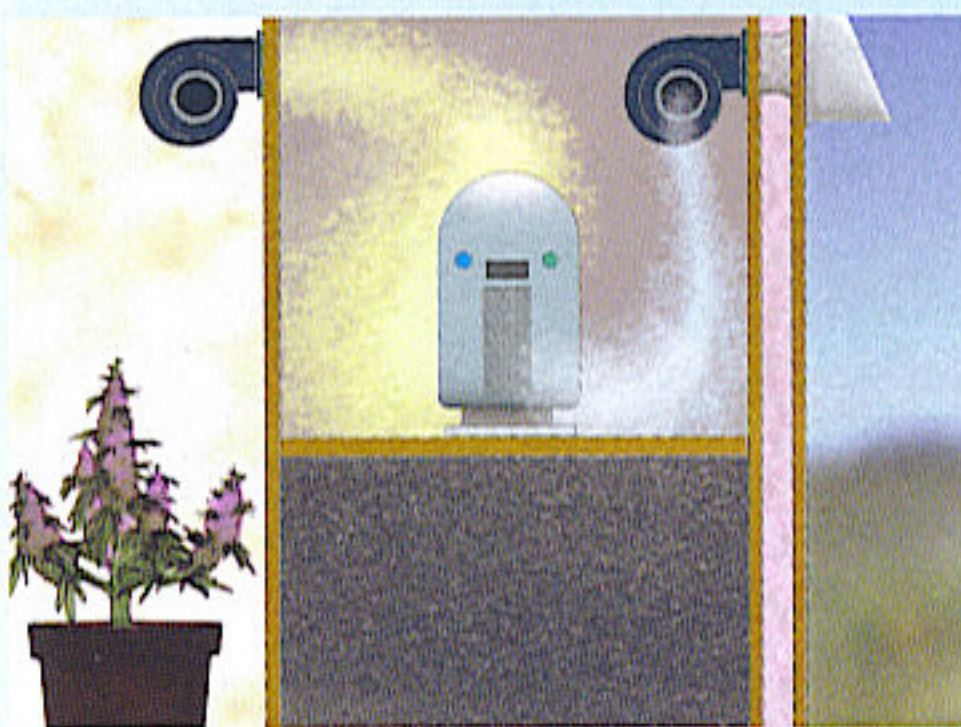
There are many ozone generators available. When shopping for an ozone generator, look for one that has been on the market for a few years and has an established track record. Watch for important features such as self-cleaning (or easy to clean) and easy, safe bulb replacement. When UV light encounters moisture in the air, nitric acid is produced as a byproduct. This white, powdery nitric acid collects around the lamps at connection points. This is an unpleasant, very corrosive acid that will severely burn skin and eyes. Verify that the ozone generator has proper safety features built in, such as a switch that turns off the lamp for maintenance, making it impossible to look at the retina-searing UV rays. Legal exposure for humans is about 0.1 ppm for a maximum of 8 hours. Most grow room ozone generators produce about 0.05 ppm at timed intervals. See below for plant symptoms of ozone overdose.

UV light is very dangerous. In a flash, intense UV light can burn your skin and the retinas in your eyes beyond repair. Never, under any circumstances, look at the UV lamp in an ozone generator. Sneaking a peek at a UV lamp in an ozone generator has cost more than one aspiring grower their eyesight! Ozone is also capable of burning your lungs. At low levels, there is no damage, but at higher levels, danger is imminent. Never, never use too much!

The Air Tiger™, manufactured by Rambridge, www.rambridge.com, is an excellent value for growers. It is one of the safest available and easy to maintain. A deadman's switch makes direct eye contact with the 10-inch-long UV light tube



The Air Tiger is a very popular ozone generator that is designed to fit inside ductwork.



Mixing ozone-treated air for a minute or more allows O_3 to shed a molecule and become O_2 .

impossible. Highly corrosive ozone stays away from interior wiring, and little moisture can penetrate the outer shell to combine with O_3 to form powdery nitric acid.

Ozone generators are rated by the number of cubic feet (m^3) they are able to treat. (To figure cubic feet or meters, multiply the length $\times$ width $\times$ height of the room). Some growers setup the ozone generator in the grow room and let it treat all the air in the room. They add a timer so the ozone generator intermittently disperses ozone into the room to maintain a relatively constant level. This practice can diminish the fragrance of the bud. Smart growers set up an ozone generator in a spare closet or build an ozone exchange chamber and route fragrant grow room air



A vent-fan duct hooks to each tube, and the air-cleansing agent is imparted before air is evacuated.



Ozone generators are located inside ducting. Grow room air mixes with ozone in ducting and big metal box. Air smells fresh and clean once treated properly with ozone.

through the closet for ozone treatment before being evacuated outdoors. Other growers set up the ozone generator in ventilation ductwork to treat air before it exits. Once generated, ozone has a life of about 30 minutes. It takes a minute or two for the O_3 molecules to combine with oxygen to neutralize odors.

Ozone damage

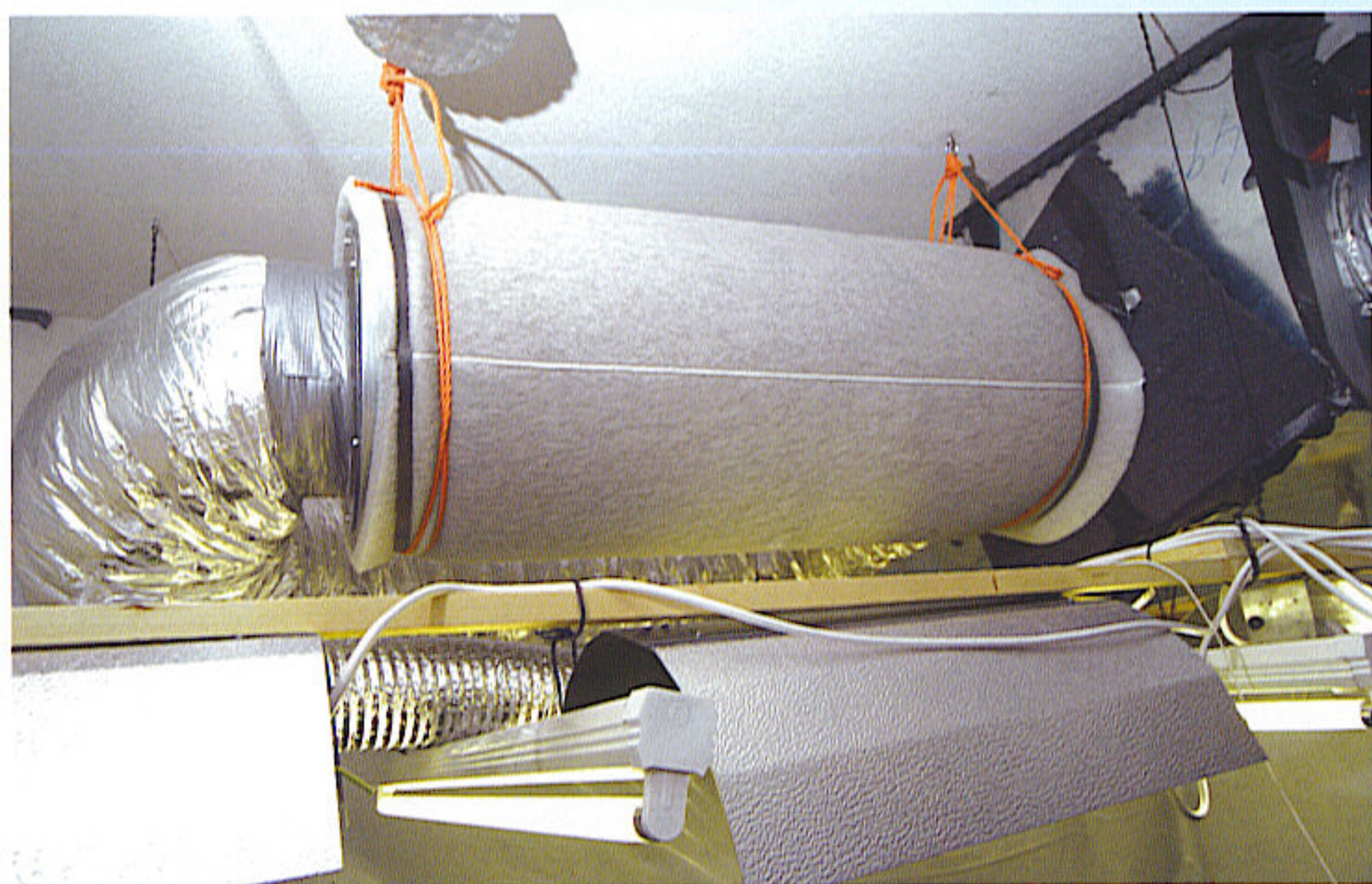
For best results, keep the ozone generator in another room or isolated from the growing plants. Ozone causes chlorotic spots on leaves. The mottled spots that appear at first to be a Mg deficiency, increase in size and turn dark in the process. Most often, the symptoms are found on foliage near the generator. Leaves wither and drop, and overall plant growth slows to a crawl.

Activated Carbon Filters

Activated charcoal filters are fantastic, and they work! The charcoal is "activated" with oxygen, which opens millions of pores in the carbon. The activated charcoal absorbs odor molecules and other pollutants in the air. The mechanics are simple, and there are three important things to remember when using a charcoal filter. First, keep room humidity below 55 percent. At about 65 to 70 percent relative humidity, the charcoal absorbs moisture and clogs. At 80 percent humidity, it stops removing odors. Second, air must move slowly through charcoal filters to extract odors. The fan on professional units lets just enough air through the filter so the odors have enough (dwell) time to be absorbed by



Ozone can severely damage foliage. This is what it does to foliage.



Charcoal filters remove fragrance and pollen from the air. The model shown above has a half-inch outer filter that encases porous ducting surrounded by activated charcoal. These filters are efficient until humidity climbs beyond 60 percent, at which point moisture-filled charcoal fails to absorb.

the carbon filter. Third, use a pre-filter. The pre-filter catches most of the dust and airborne pollutants before they foul the carbon filter. Change the pre-filter regularly—every 60 days, or more often if the room is dusty. Carbon lasts about a year. Many growers prefer activated carbon made from coco. Do not use activated carbon that is “crushed,” because it is less efficient than charcoal pellets.

Install an intake screen that filters out large particles of dust to prolong the life of the activated charcoal filter. Whether the intake is passive or brought in by a fan, use a filter for incoming air to minimize pollutants in the grow room.

Check with filter manufacturers or retailers about venting specifications for your grow area. A more powerful exhaust fan will be necessary to draw an adequate volume of air through the activated charcoal filter. An adequate airflow is imperative to keep a high CO₂ content in the grow room air.

Setting Up the Vent Fan - Step-by-Step

Step One: Figure the total volume of the grow room. Length × width × height = total volume. For example, a grow room that is 10 × 10 × 8 feet (21.5 m³) has a total volume of 800 cubic feet (10 × 10 × 8 feet = 800 cubic feet (21.5 m³)). A room measuring 4 × 5 × 2 meters has a total volume of 40 cubic meters.

Step Two: Use a vent fan that will remove the total volume of air in the room in less than five minutes. Buy a fan that can easily be mounted on the wall or “in line” in a duct pipe. Quality “in line” fans move much air and make very little noise. It’s worth spending the extra money on an “in line” fan. Small rooms can use a fan that can be attached to a flexible 4-inch (12 cm) dryer hose. Many stores sell special ducting to connect high-speed squirrel cage fans with the 4-inch (12 cm) ducting.

Step Three: Place the fan high on a wall or near the ceiling of the grow room so it vents off hot, humid air.



An activated charcoal filter is attached to a vent fan. The air is cleaned before leaving the grow room.

Step Four: If possible, cut a hole in the wall, and secure the fan in place over the hole. Most locations require special installation. See: Steps 5-9 below.

Step Five: To place a fan in a window, cut a 0.5-inch (1.5 mm) piece of plywood to fit the windowsill. Cover window with a lightproof dark-colored paint or similar covering. Mount the fan near the top of the plywood so it vents air out of the grow room. Secure the plywood and fan in the windowsill with sheet rock screws. Open the window from the bottom.

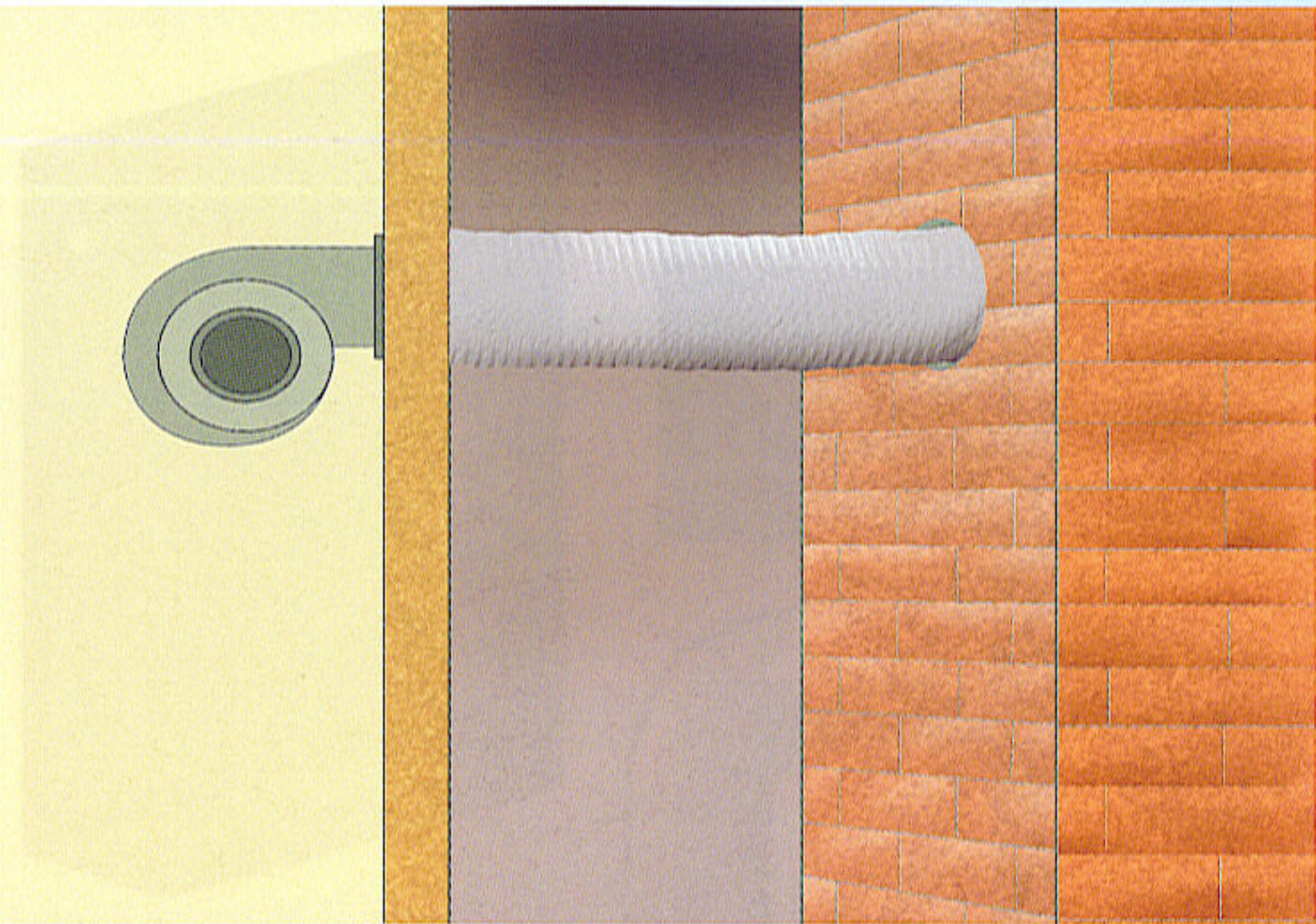
Step Six: Another option to make a lightproof vent is to use 4-inch (12 cm) flexible dryer ducting. Vent the hose outdoors, and attach a small squirrel cage fan to the other end of the ducting. Make sure there is an airtight connection between the fan and hose by using a large hose clamp or duct tape. Stretch the flexible ducting so it is as smooth as possible inside. Irregular interior surfaces cause air turbulence

and seriously diminish airflow.

Step Seven: Another option is to vent the air



Can carbon filters are available in many sizes and are a popular brand.



Air is deodorized by an ozone generator that is inside this ducting.

up the chimney or into the attic where light leakage and odor are seldom a problem. If using the chimney for a vent, first clean out the excess ash and creosote. Tie a chain to a rope. Lower the chain down the chimney, banging and knocking all debris inside to the bottom.

There should be a door at the bottom to remove the debris. This door is also used as the exhaust vent.

Step Eight: Attach the fan to a thermostat/humidistat or other temperature/humidity monitor/control device to vent hot, humid air outside. Set the temperature on 75°F (24°C) and the humidity on 55 percent in flowering rooms and 60 to 65 percent in vegetative rooms. Most control devices have wiring instructions. More sophisticated controllers have built-in electrical outlets, and the peripherals are simply plugged into them.

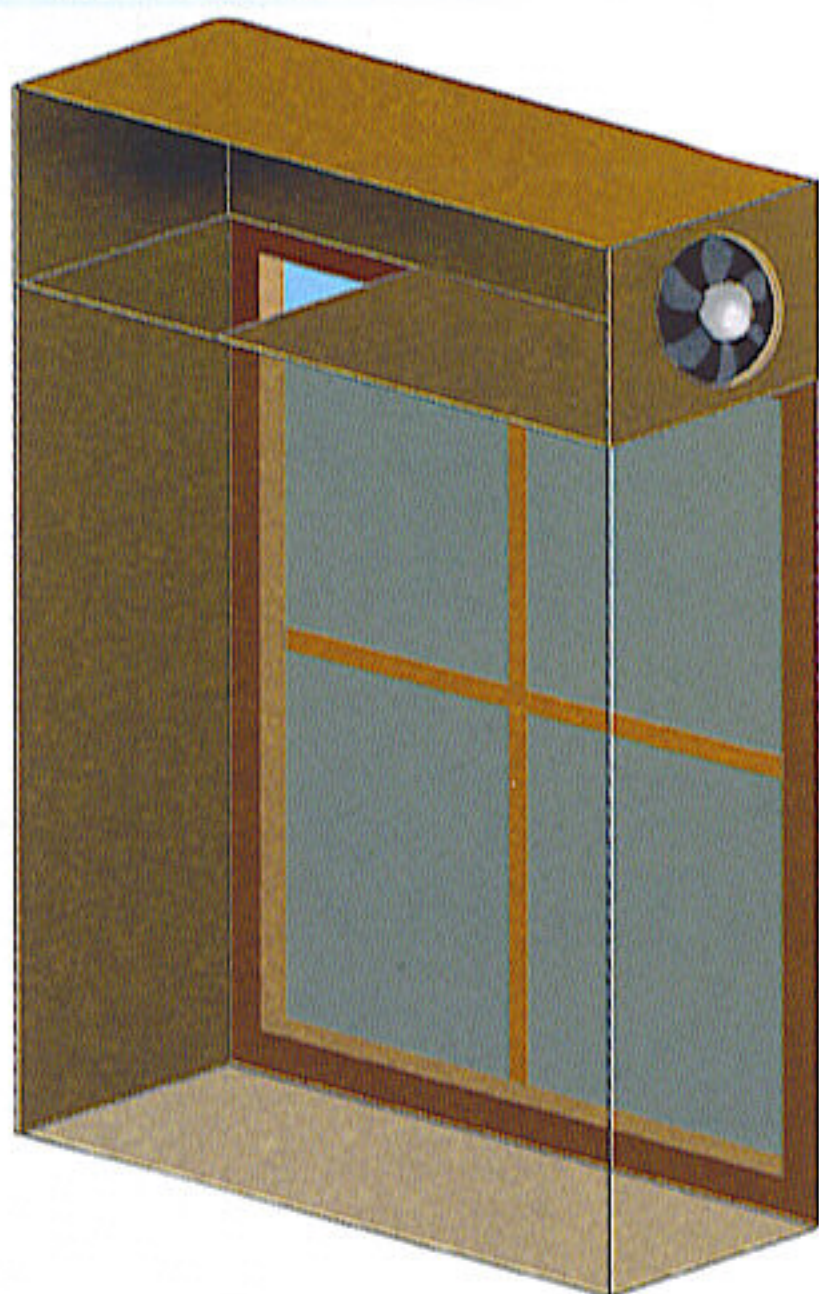
Step Nine: Or attach the vent fan to a timer and run it for a specific length of time. This is the method used with CO₂ enrichment. Set the fan to turn on and vent out used CO₂-depleted air just before new CO₂-rich air is injected.



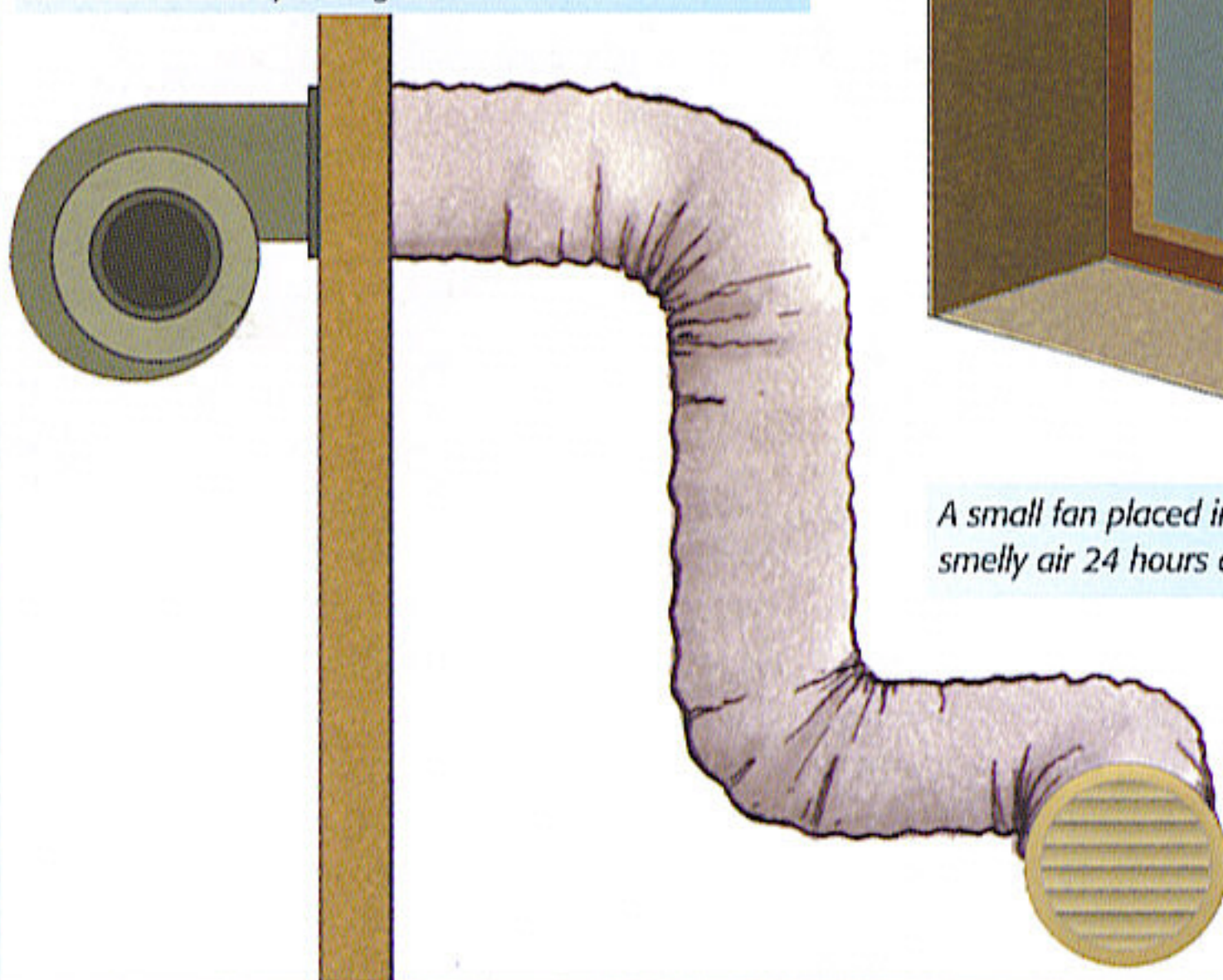
Air flow and volume are diminished when they turn corners.



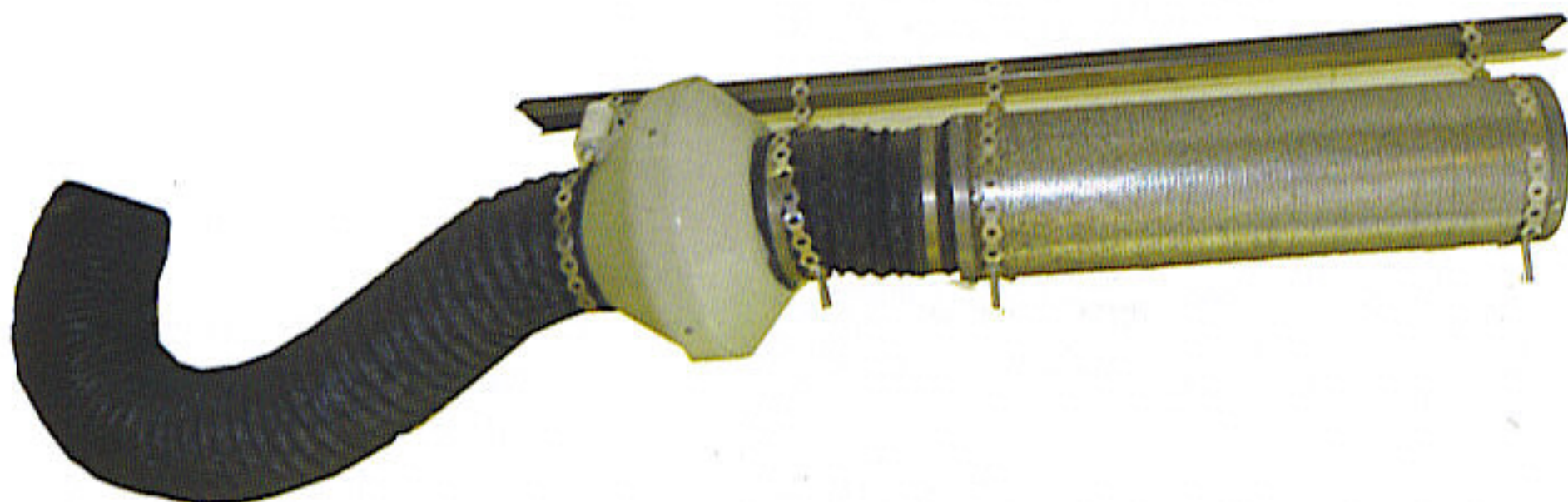
This grower uses insulated ducting to dampen noise and vibrations caused by moving air.



A small fan placed in a window box removes smelly air 24 hours a day.



Turning air around a corner keeps grow room light from signaling passersby.



Here is a charcoal filter without the outer dust filter. The in-line fan adds extra suction to pull and push air through flexible ducting before it meets the extraction fan at the end of the duct.